First results from the ALICE experiment

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for the ALICE collaboration

Outline

- ALICE experiment at CERN LHC
  - Motivation for doing the pp measurements
  - Trigger, data samples and event classes
  - Detector performance
- The first results :
  - Multiplicity
  - Charged particle spectra
  - Baryon production
  - Bose-Einstein correlations
  - Identified particle spectra
  - Jet and underlying event properties
  - Heavy Flavour production

published (Multiplicity, Charged particle spectra, Baryon production, Bose-Einstein correlations)

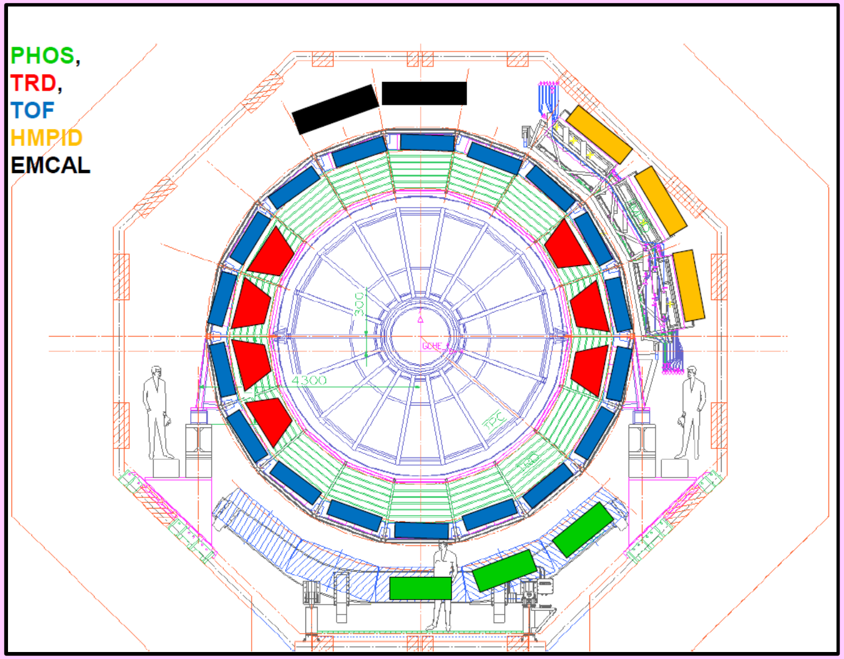
preliminary (Identified particle spectra)

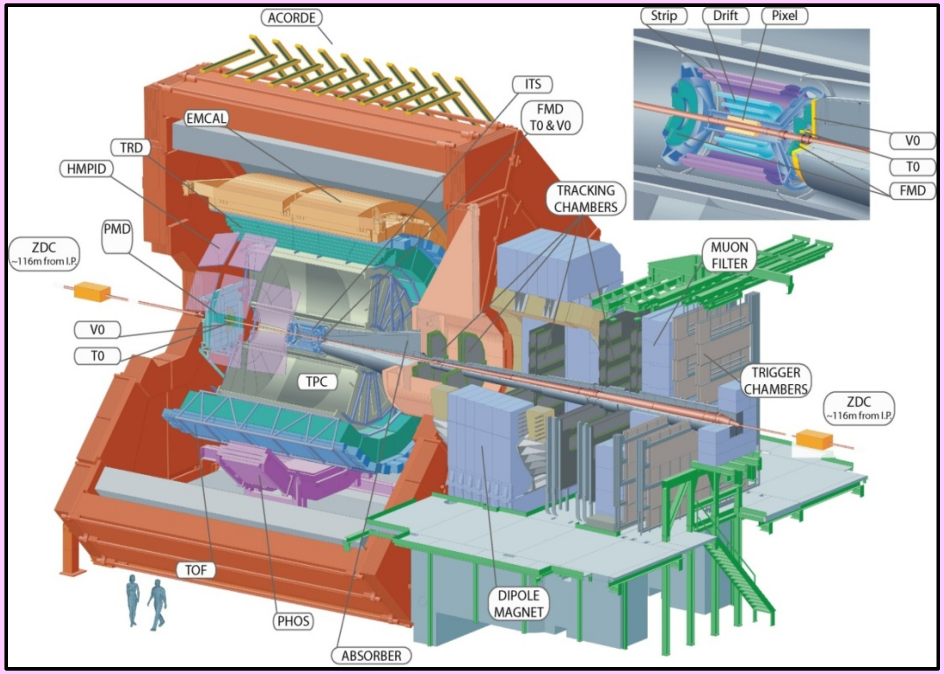
in preparation (Jet and underlying event properties, Heavy Flavour production)

The ALICE experiment

Detector configuration 2009/2010 :

- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD (7/18)
- EMCAL (4/12)
- PHOS (3/5)





Detector:

Size: **16 x 26** meters

Weight: **10,000** tons

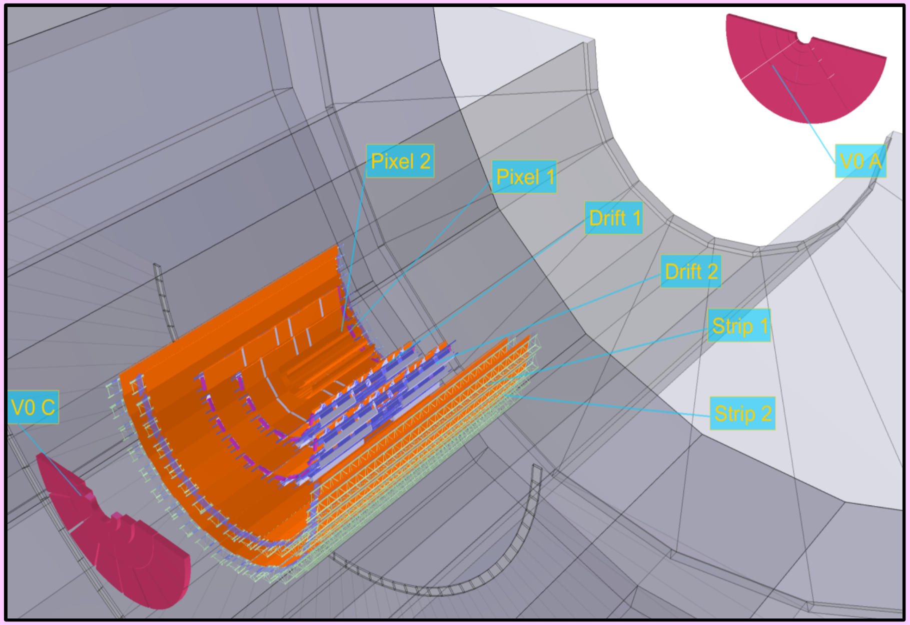
Collaboration:

> 1000 Members
> 100 Institutes
> 30 countries

Physics motivation in pp

- The main goal of the ALICE experiment: properties of strongly interacting matter (QGP) created in HE nucleus-nucleus collisions
  - Necessity of the hadronic reference for the observables
- Understanding the particle production in the new energy domain
  - Comparison with models
- Search for collective effects at the partonic level
  - Multiplicity dependence of the measurement results

Trigger and data samples



- "Minimum bias" trigger: at least one charged particle in 8 units of η (All ALICE is read out)
  - SPD or V0A or V0C
- "Single-muon trigger" (MUON, SPD, V0, FMD, ZDC are read out)
  - MUON in coincidence with the "minimum bias"
- Both in coincidence with the BPTX beam pickup counters

Available statistics:

2009 (0.9 and 2.36 TeV): ~ 0.5 M min. bias

2010 (0.9 and 7 TeV): ~400 M min. bias(~15 M MUON trg)

Event classes

0.9 and 2.36 TeV

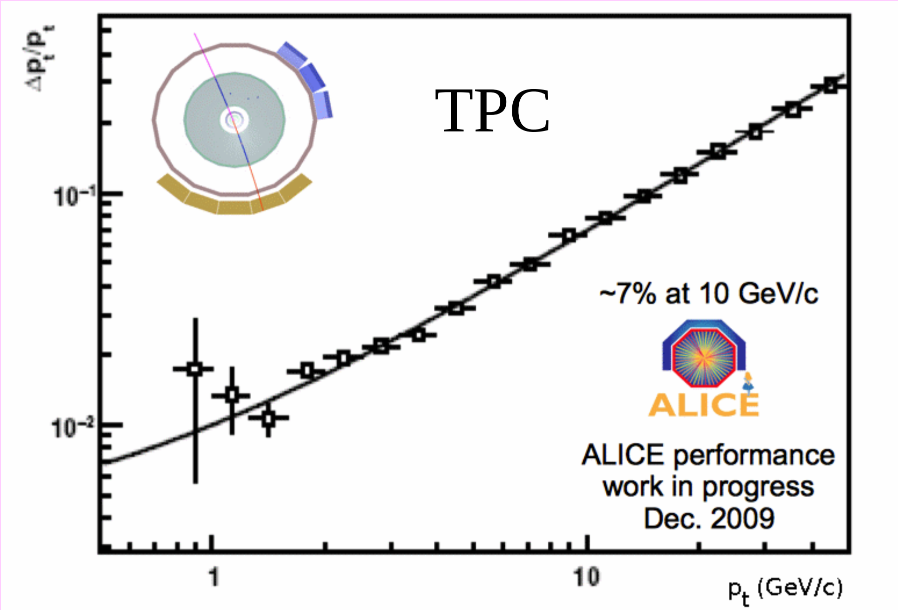
- INEL and NSD
- Use measured cross sections for diffractive processes
- Change MC generator fractions (SD/INEL, DD/INEL) so that they match these fractions
- Use Pythia and Phojet to assess effect of different kinematics of diffractive processes

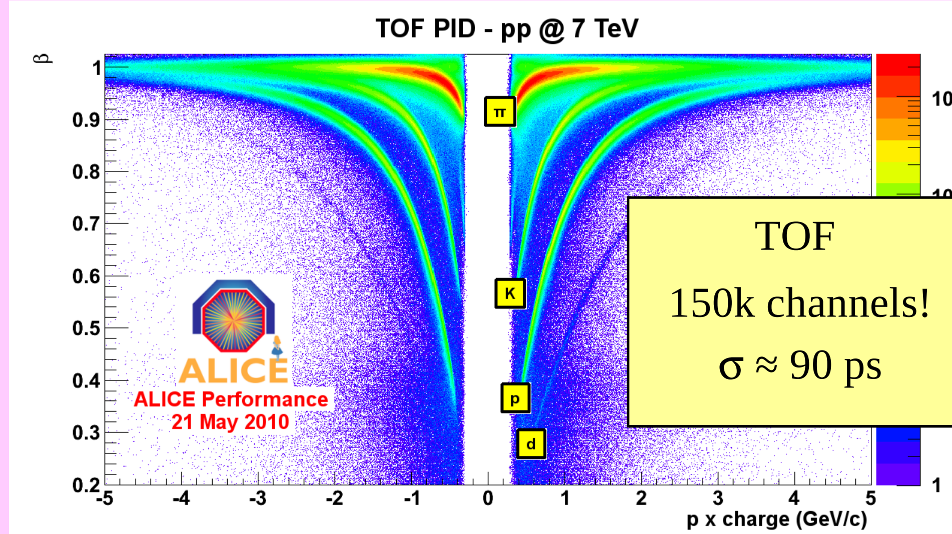
7 TeV

- Diffraction is quite unknown
- Hadron-level definition of events (similar to ATLAS: Phys. Lett. B 688 (2010) 21)
  - All events that have at least one charged primary particle in $|\eta|<1$ “INEL>0”
  - Minimizes model dependence

INEL: MB_{OR} (SPD *or* VZEROA *or* VZEROC) *and* offline background suppression
NSD: MB_{AND} (VZEROA *and* VZEROC) *and* offline background suppression
INEL>0: INEL *and* at least one charged primary particle in $|\eta| < 1$

ALICE detector performance

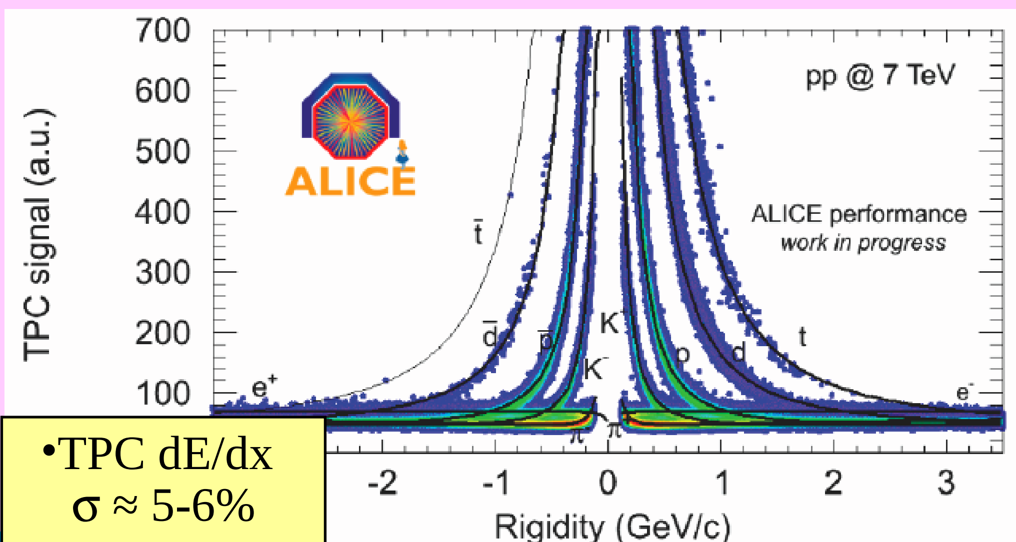




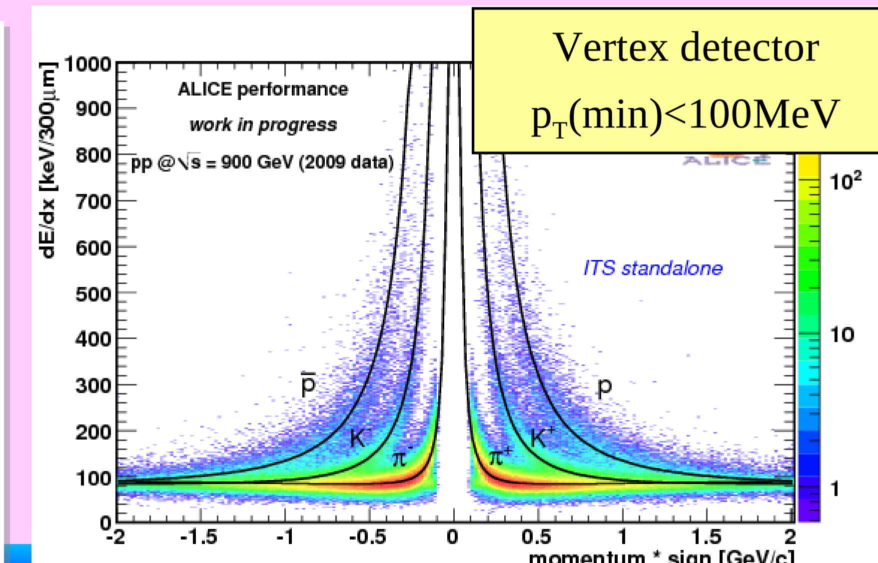
TOF

150k channels!

σ ≈ 90 ps



•TPC dE/dx
σ ≈ 5-6%

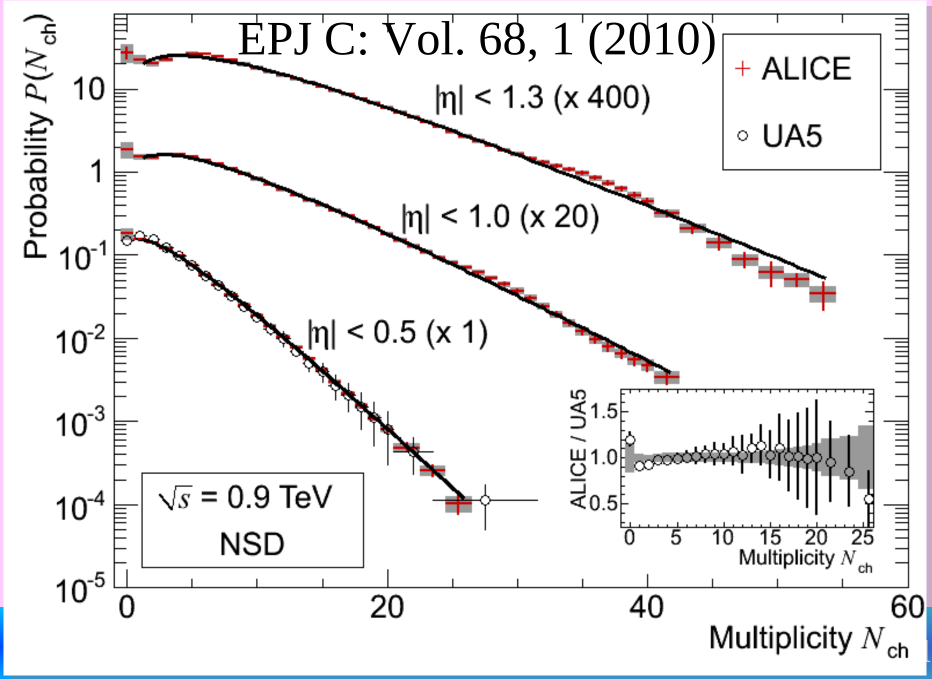


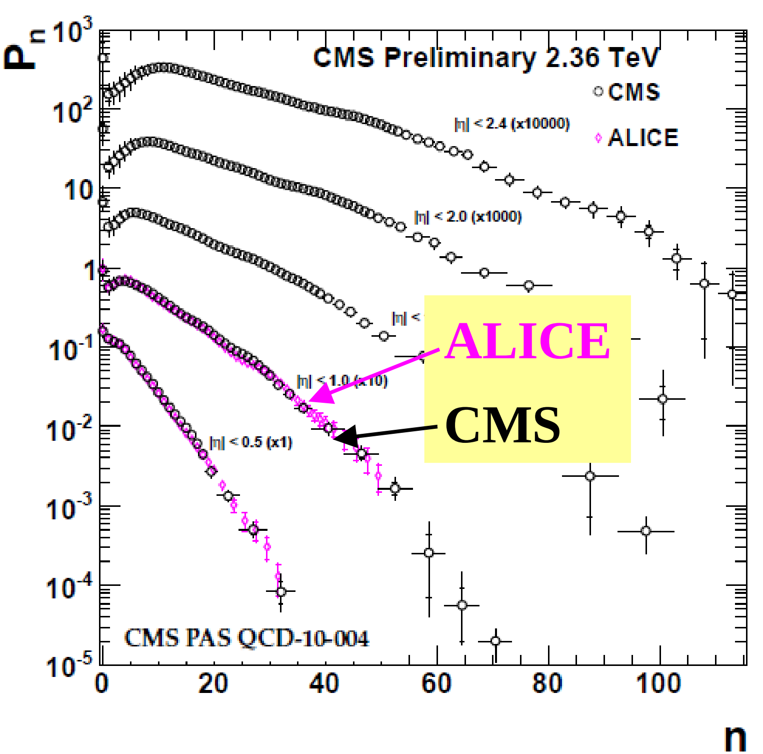
Vertex detector

$p_T(min)<100MeV$

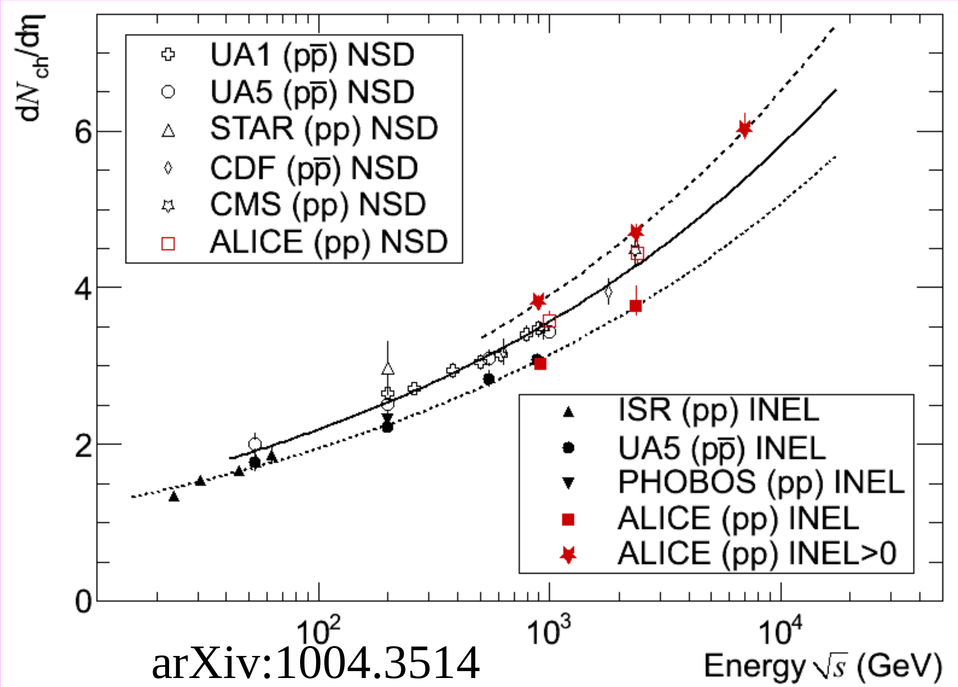
Multiplicity measurements
(Done with SPD, r ~4 and 7 cm)

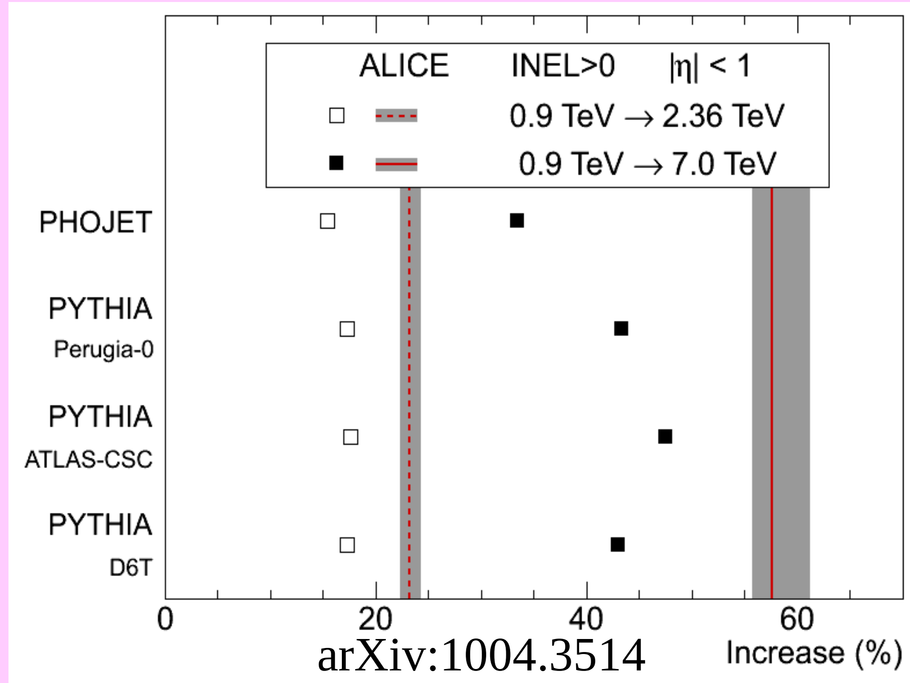
- Pseudo-rapidity densities and multiplicity distributions:
  - 0.9 TeV: **EPJC** Vol. **65** (2010) 111
  - 0.9 and 2.36 TeV: **EPJC** Vol. **68** (2010) 89
  - 7 TeV: **arXiv:**1004.3514, accepted by EPJC
- Multiplicity distributions well described by single negative binomial distributions and consistent with the results by other experiments.





Multiplicity: $dN_{ch}/d\eta$ *vs* $\sqrt{s}$



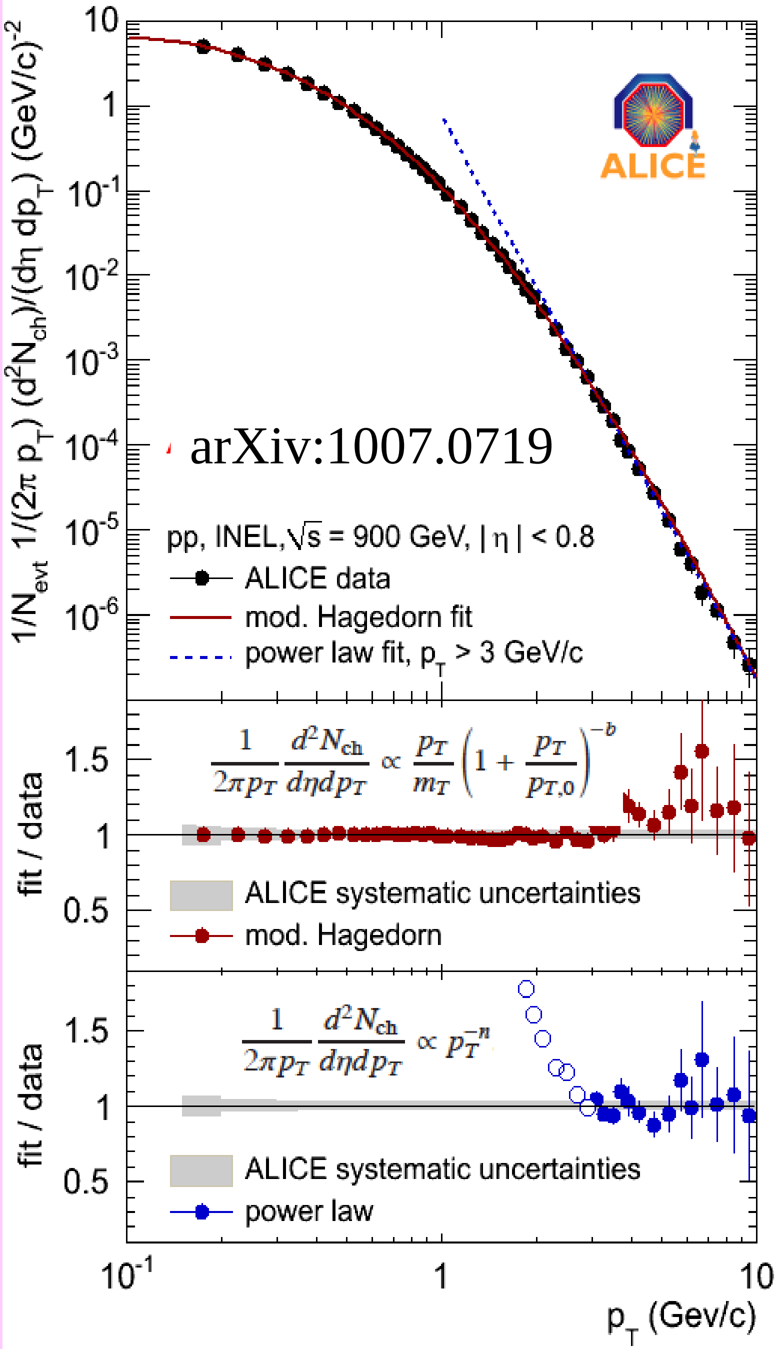


Power law dependence fits well $\sim s^{0.1}$

Significantly larger increase from 0.9 to 7 TeV than in MCs

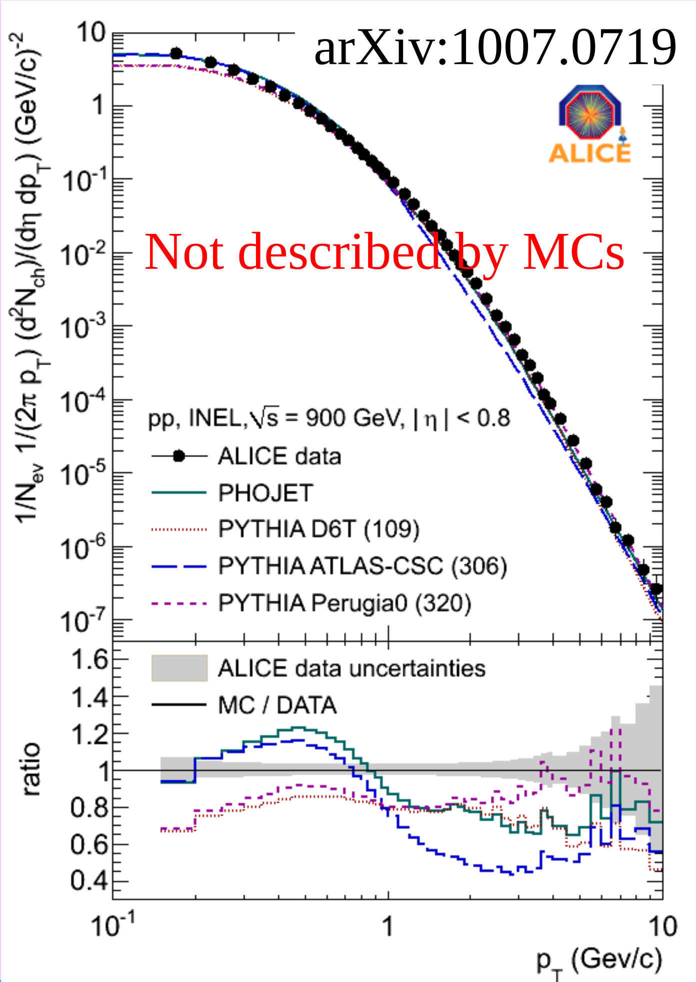
Increase in dN_{ch}/dh in $|\eta| < 1$ for INEL > 0 arXiv:1004.3514	$\sqrt{s}$	ALICE (%)	MCs (%)
	0.9 → 2.36 TeV	$23.3 \pm 0.4\ ^{+1.1}_{-0.7}$	15 – 18
	0.9 → 7 TeV	$57.6 \pm 0.4\ ^{+3.6}_{-1.8}$	33 – 48

dN_{ch}/dp_T at 0.9 TeV

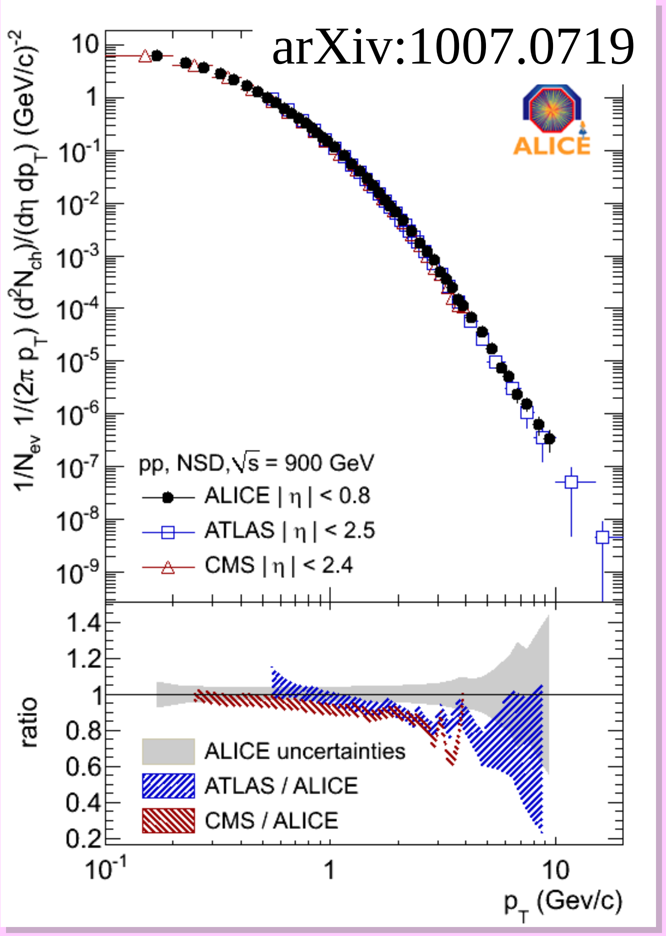


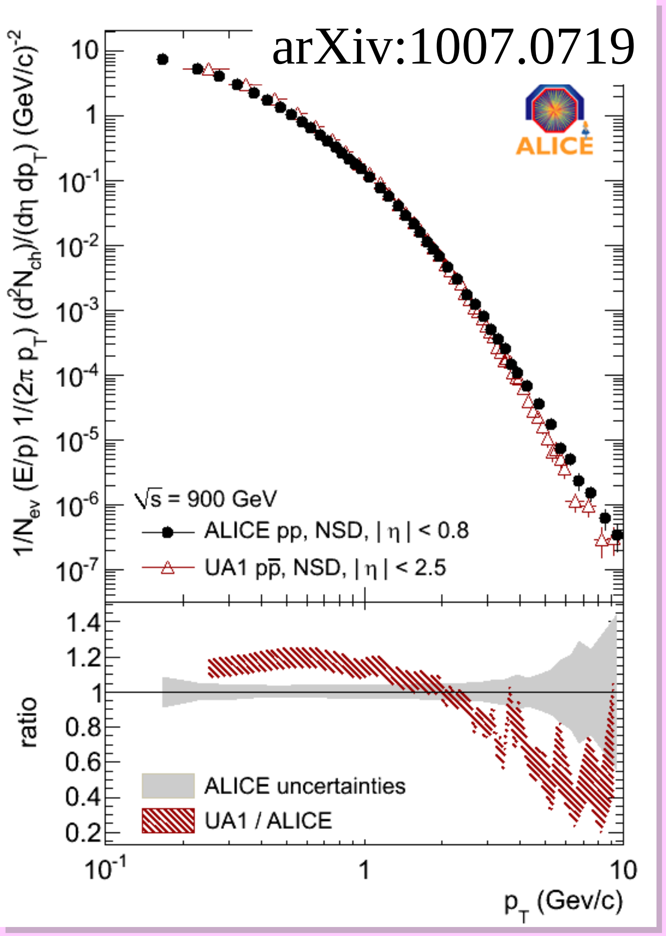
$\langle p_T \rangle_{INEL}$ = 0.483 ± 0.001 (stat) ± 0.007 (syst.) GeV/c

$\langle p_T \rangle_{NSD}$ = 0.489 ± 0.001 ± 0.007 GeV/c



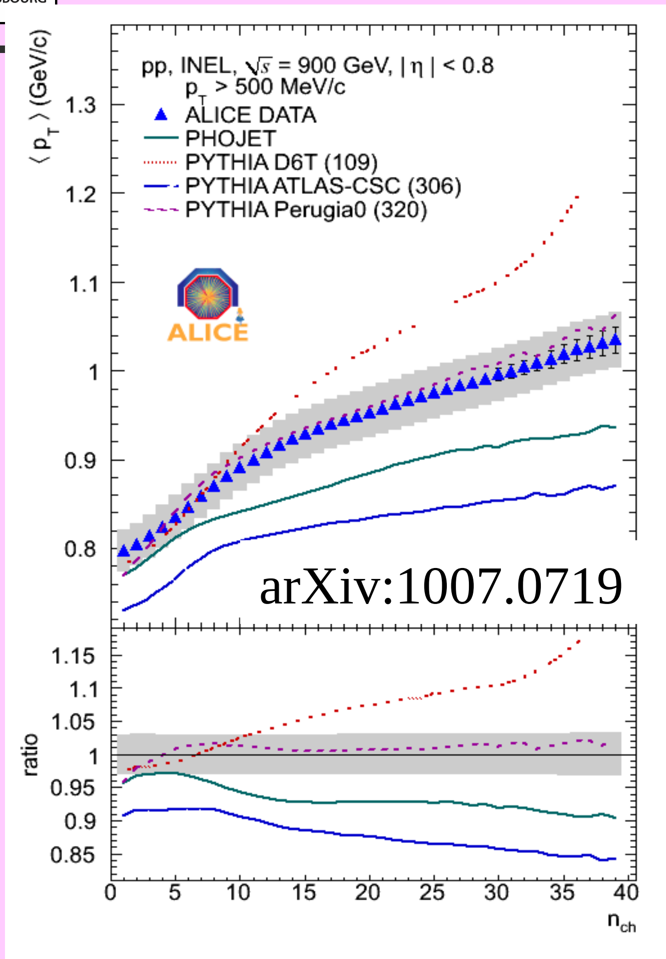
dN_{ch}/dp_T *vs* other experiments

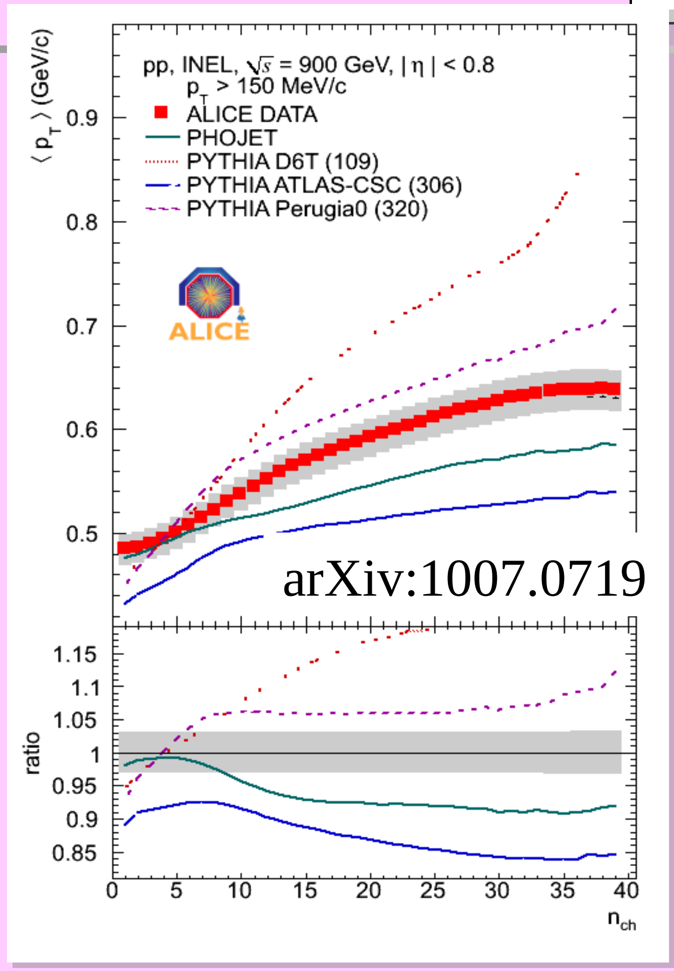




→ALICE measures harder spectrum than CMS, ATLAS, UA1 (narrower window at central rapidity)

$<p_t>$ *vs* multiplicity *vs* MC

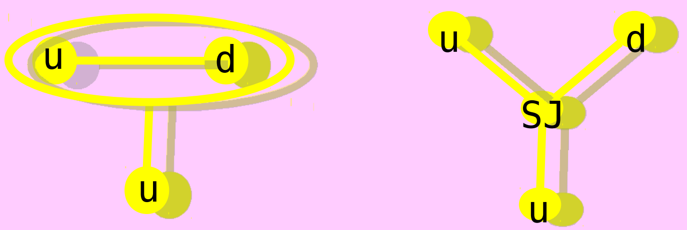




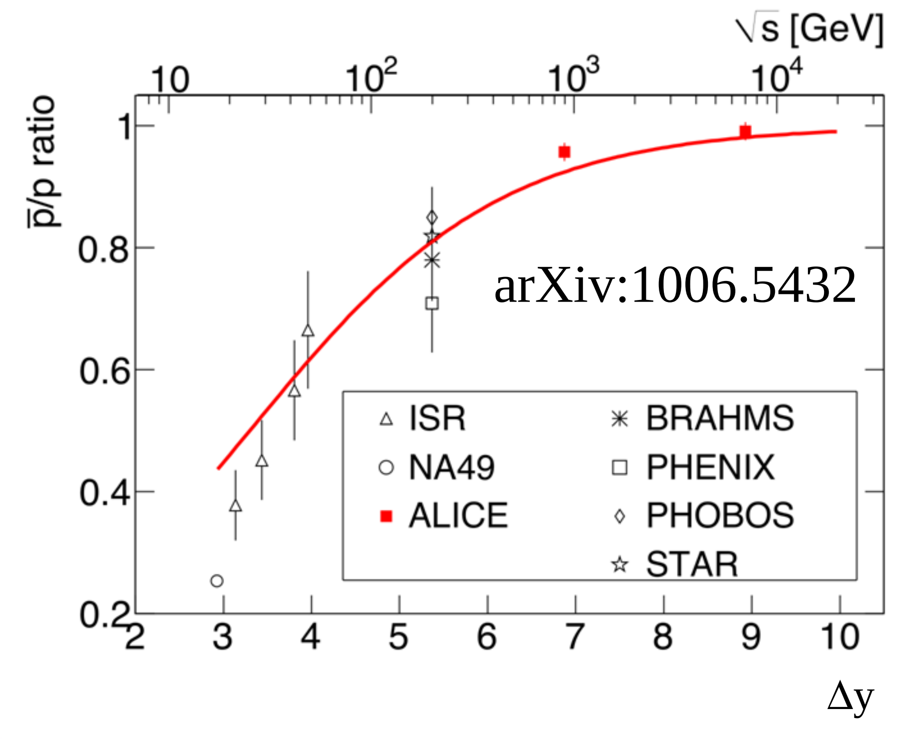
- **Perugia-0** (fails for multiplicity) describes well $<p_t>$, but only for p_t>500 MeV/c
  (ATLAS found agreement for p_t > 500 MeV/c)
- **Phojet** (describes multiplicity) fails for $<p_t>$

p̄/p measurement at mid-rapidity

- Baryon number transport by a di-quark and/or a string junction



- Valence quarks: Rossi and Veneziano, NPB123 (1977) 507
  (strong suppression with Δy)
- Gluonic field: Kopeliovich and Zakharov, ZPC43 (1989) 241
  (weak suppression with Δy)



$$\left(\frac{\bar{p}}{p}\right) = \frac{1}{1 + C \cdot e^{(\alpha_J - \alpha_P)\Delta y}} \rightarrow \begin{cases} a_J = 0.5\ (fixed) \\ a_P = 1.2\ (fixed) \\ C = 10.0 \pm 1.0 \end{cases}$$

- Proton identification with TPC dE/dx
- Special care for secondary particle contamination and absorption corrections
- pbar/p at |y| < 0.5 and 0.45 < p_t < 1.05 GeV/c

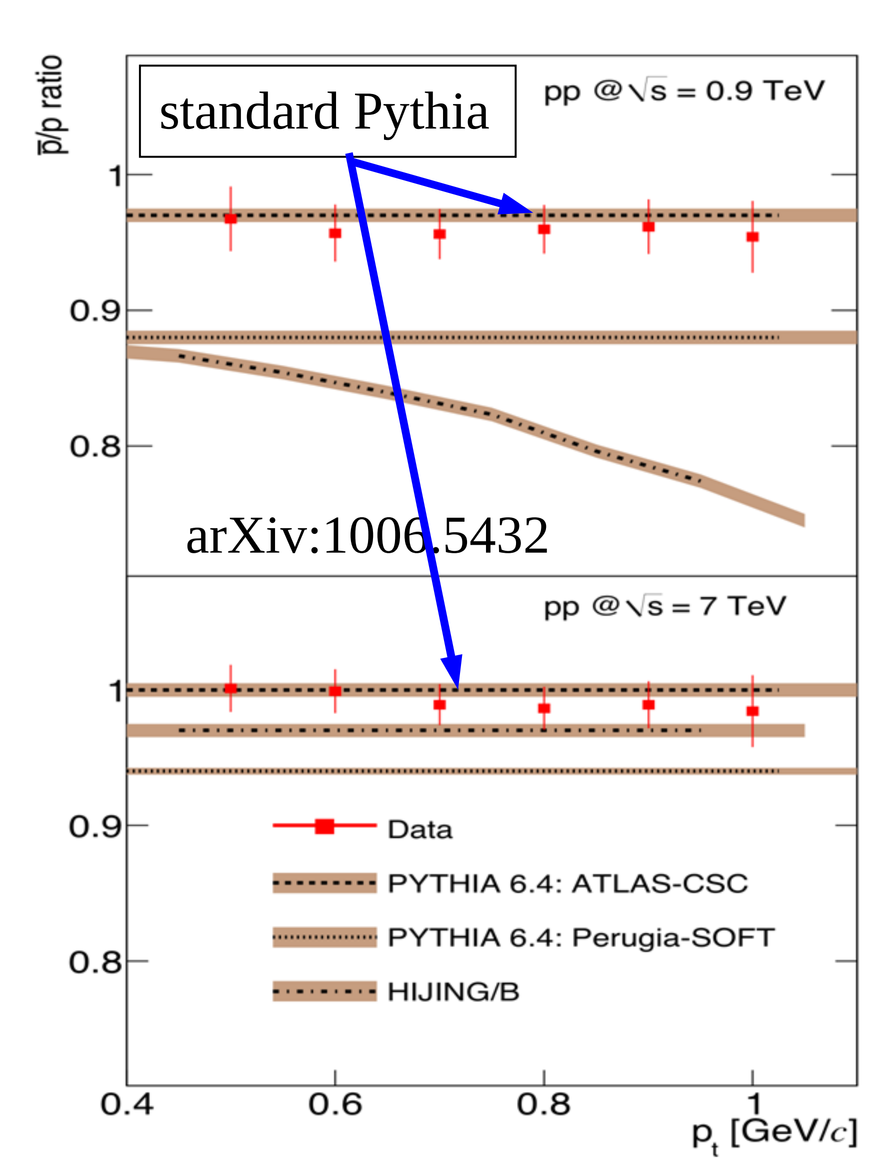
$\bar{p}$/p measurement *vs* MCs

0.9 TeV: $\bar{p}$/p = **0.957**±0.006(stat) ±0.014(syst)

7 TeV: $\bar{p}$/p = **0.990**±0.006(stat) ±0.014(syst)

- Data described well by PYTHIA ATLAS-CSC
- Other models (HIJING-B, PYTHIA Perugia-SOFT) underestimate the data
- Conclusion: The baryon number transport over large rapidity gaps is strongly suppressed.

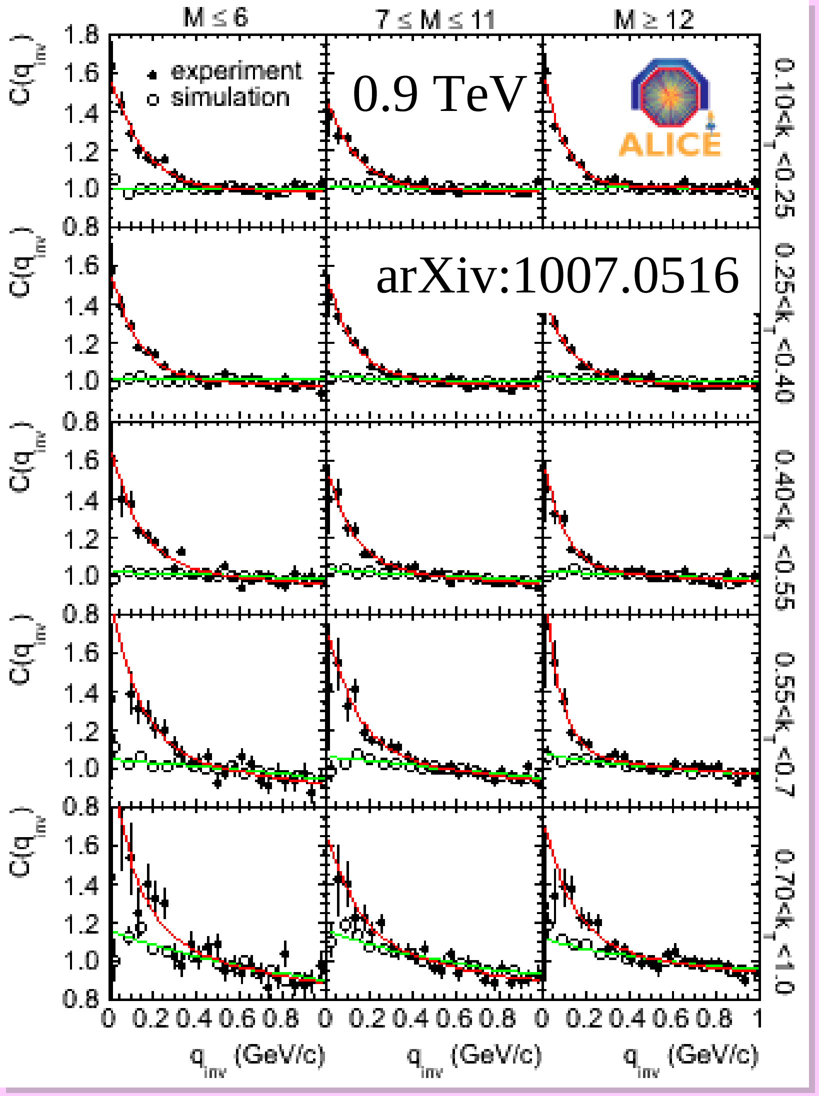
(Accepted by PRL)



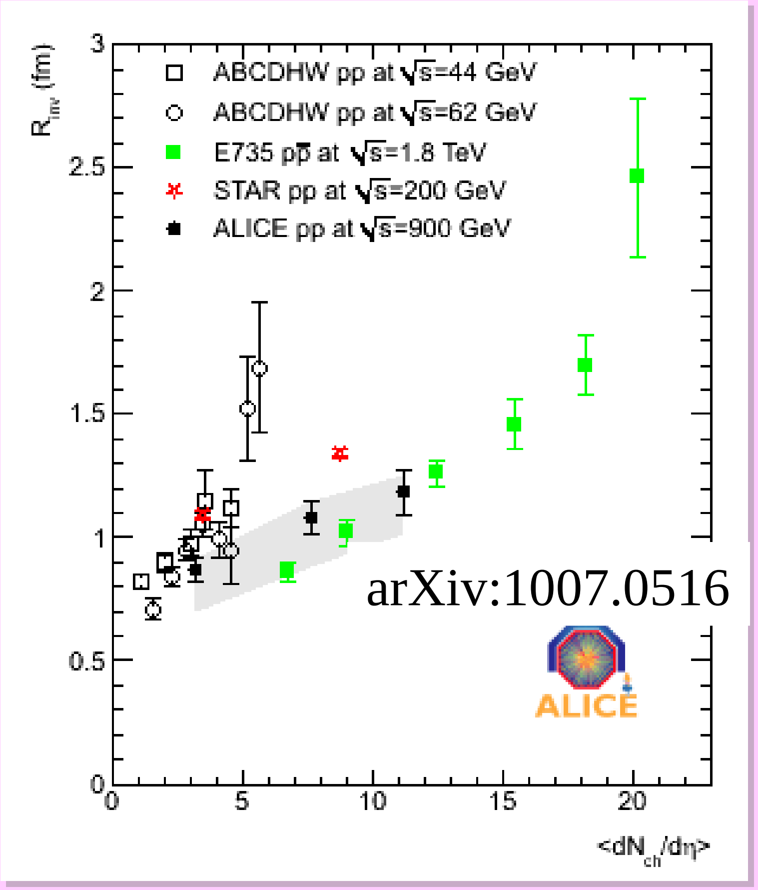
Bose-Einstein correlations

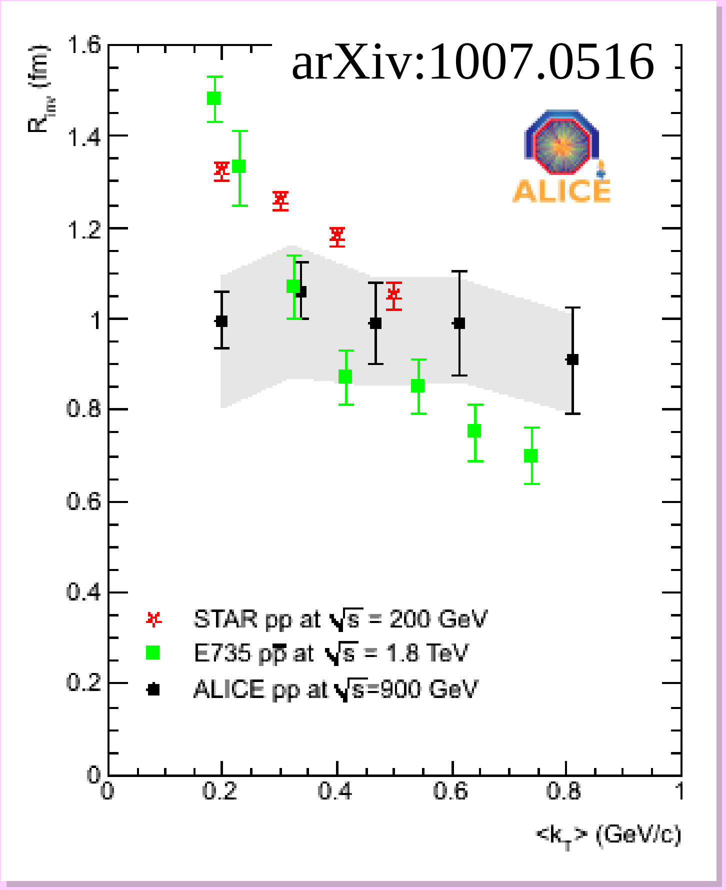
- Assess the space-time evolution of the system that emits particles in pp collisions
- Measure the Bose-Einstein enhancement for pairs of pions (identical bosons) at low momentum difference $q_{inv}=|\mathbf{p}_1-\mathbf{p}_2|$, vs. event multiplicity and pair $k_t = |\mathbf{p}_{t1}+\mathbf{p}_{t2}|/2$
- Fit with a Gaussian

$$C(q_{inv}) = 1 + \lambda \exp(-q_{inv}^2 R^2)$$



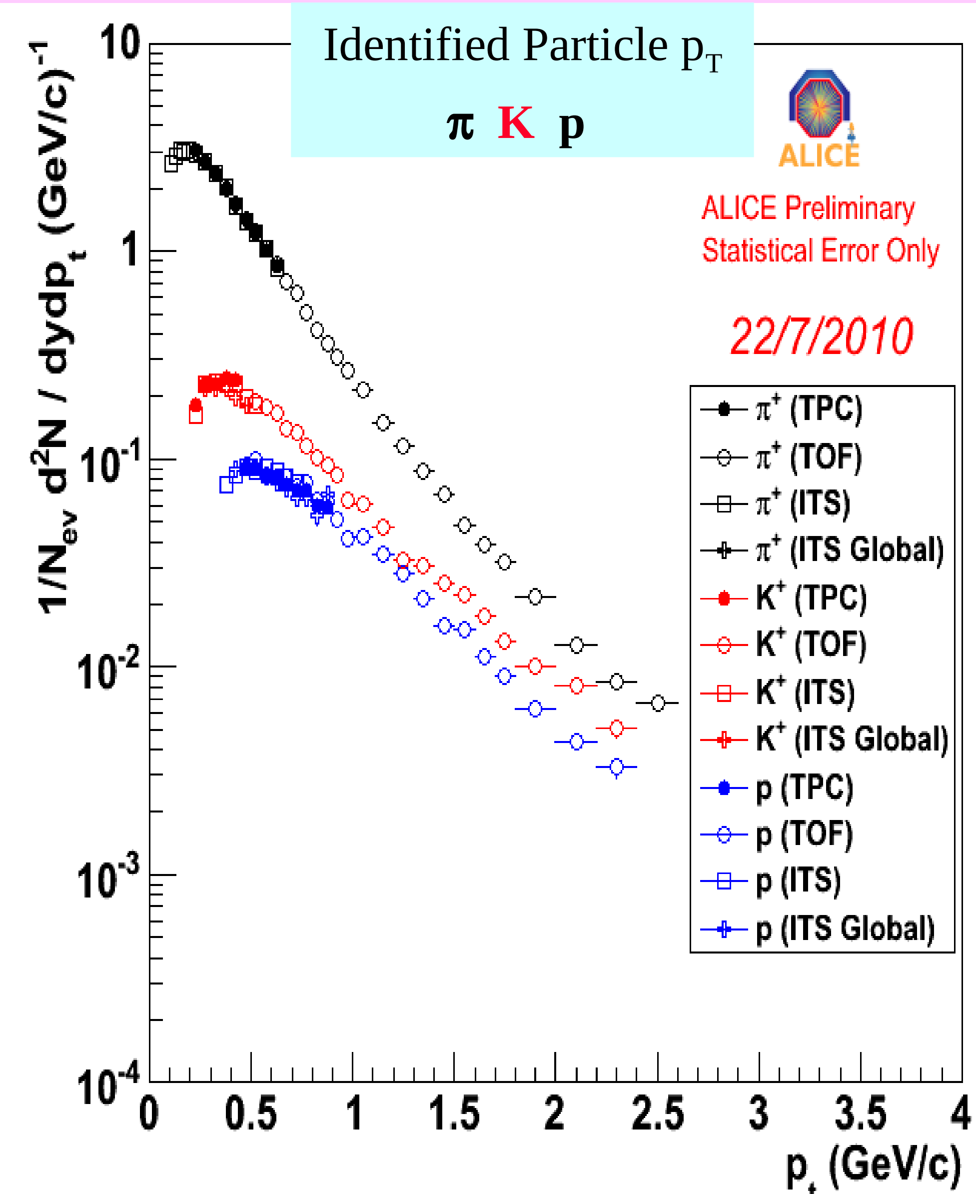
BEC *vs* other experiments

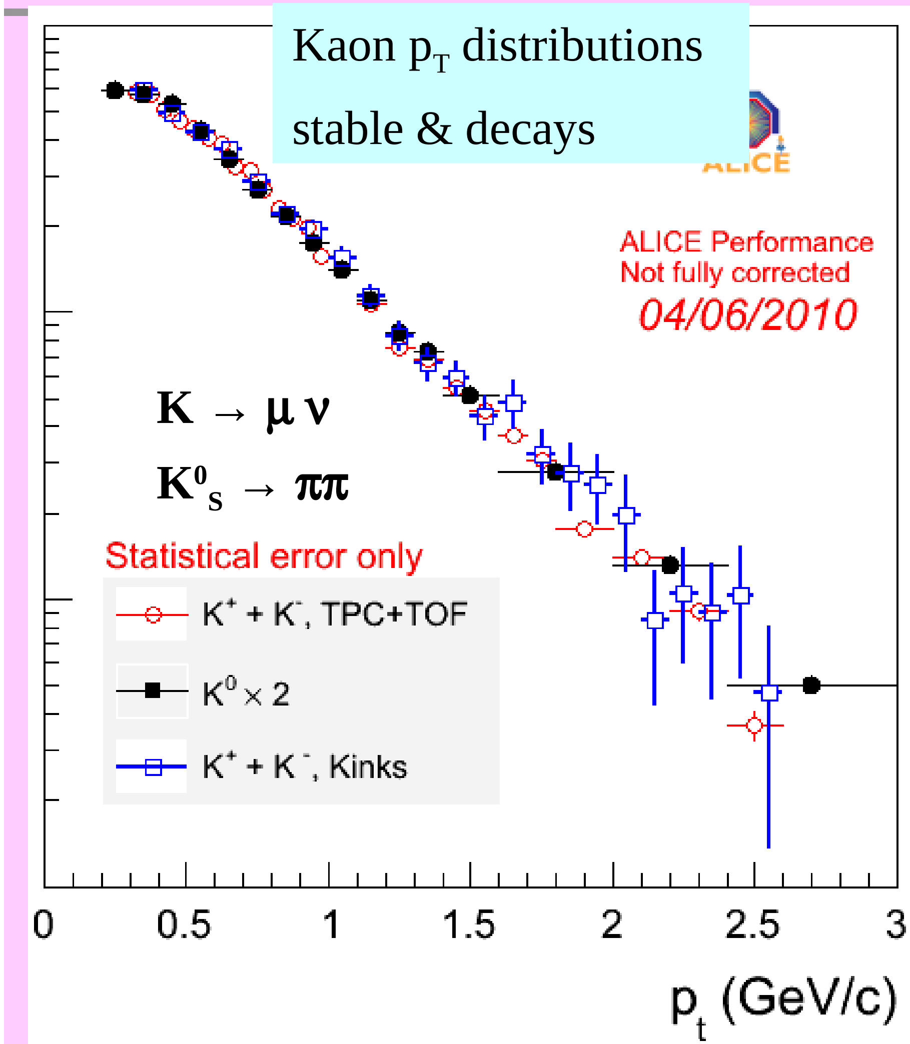




- Radius grows with $dN_{ch}/d\eta$
- No visible k_t dependence (base line !)

Identified particle spectra at 0.9 TeV





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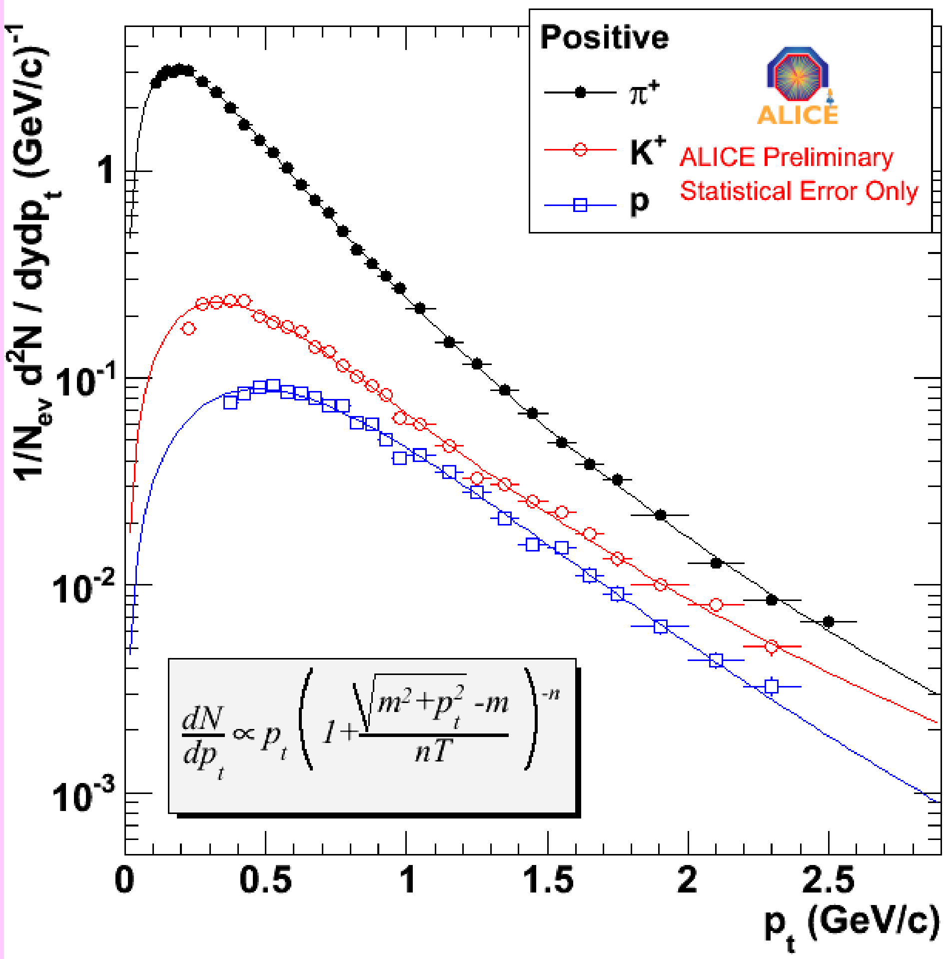
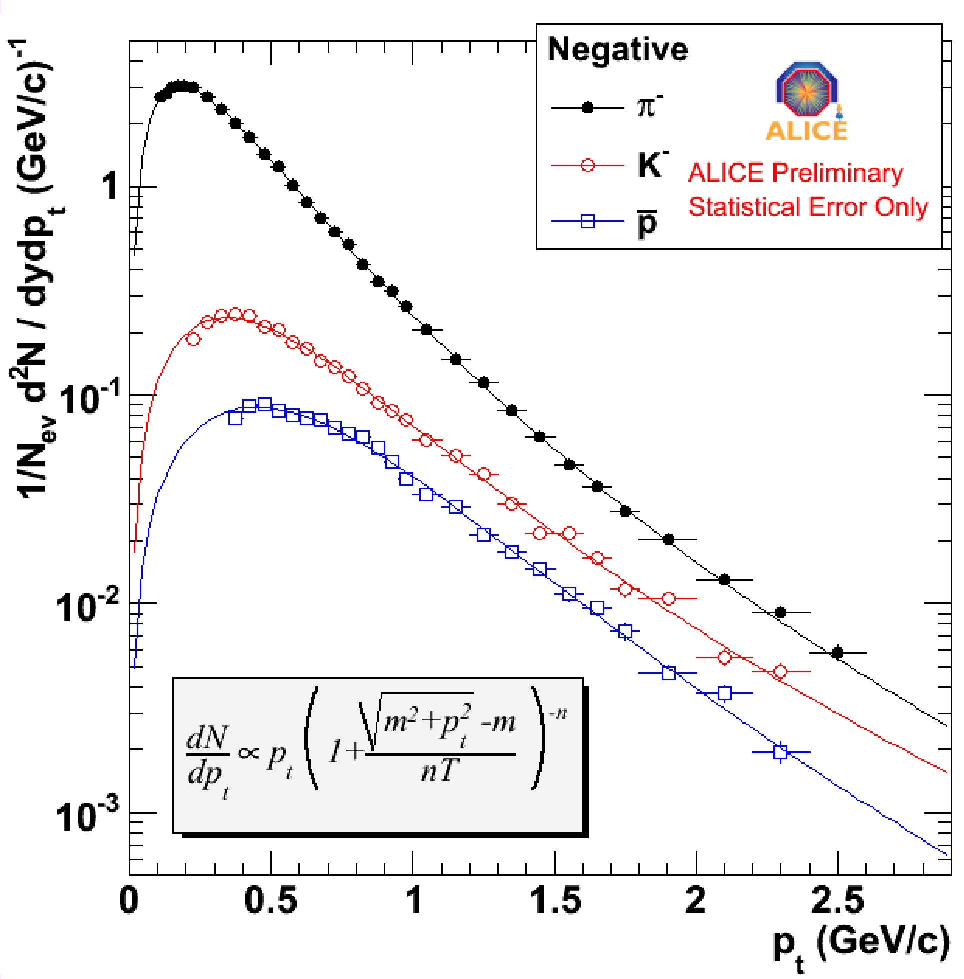
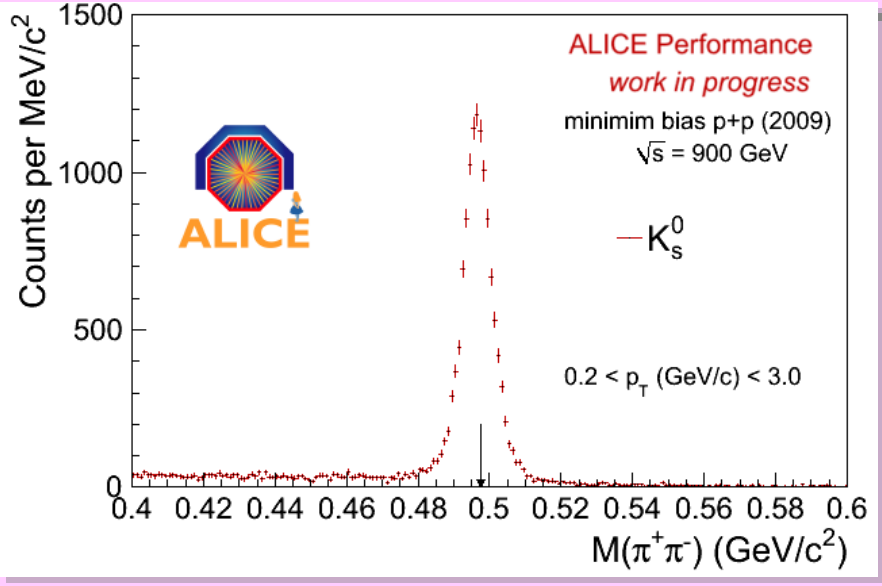
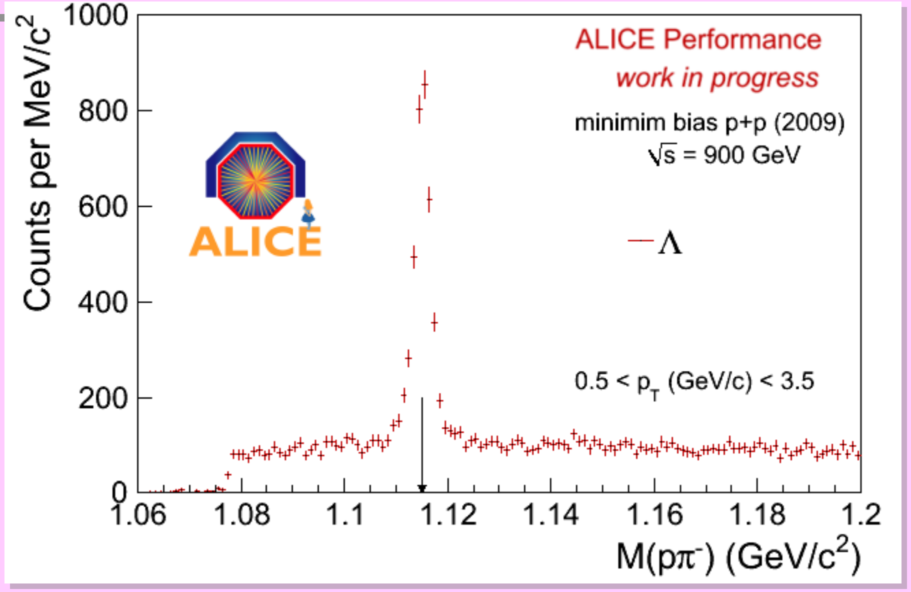
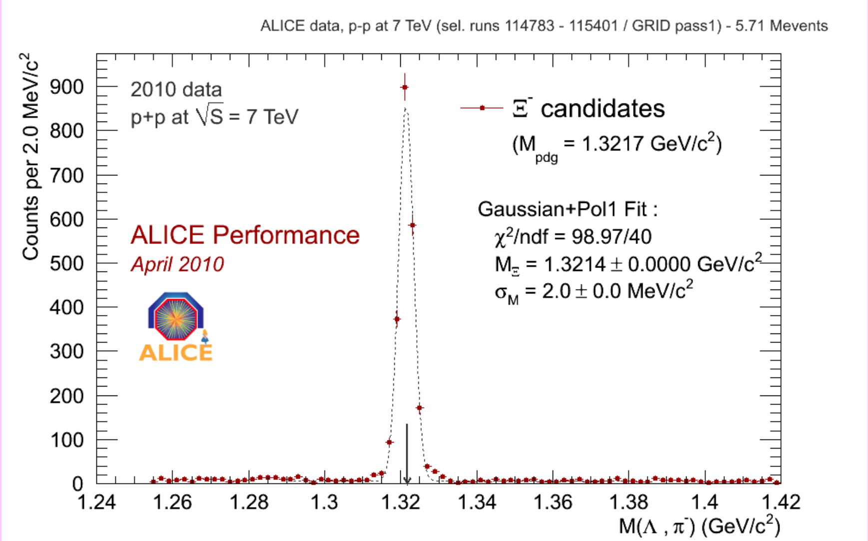


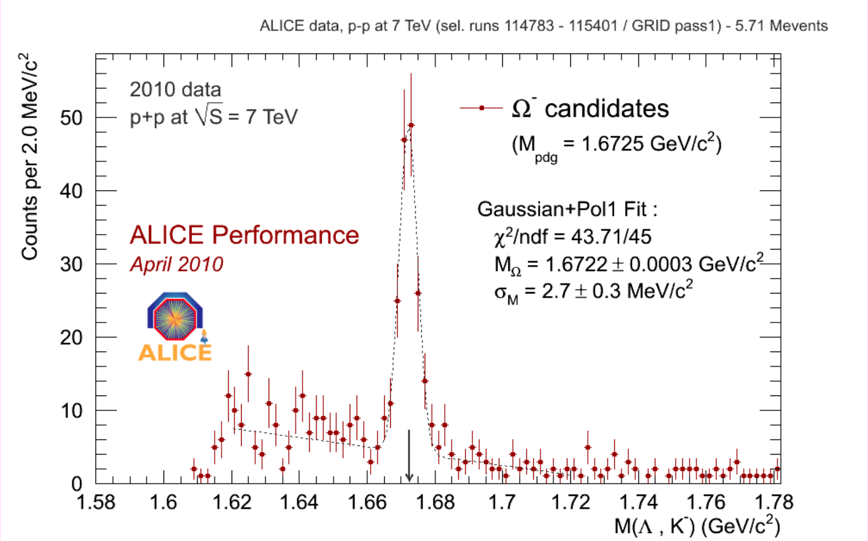


Strangeness at 0.9 and 7 TeV

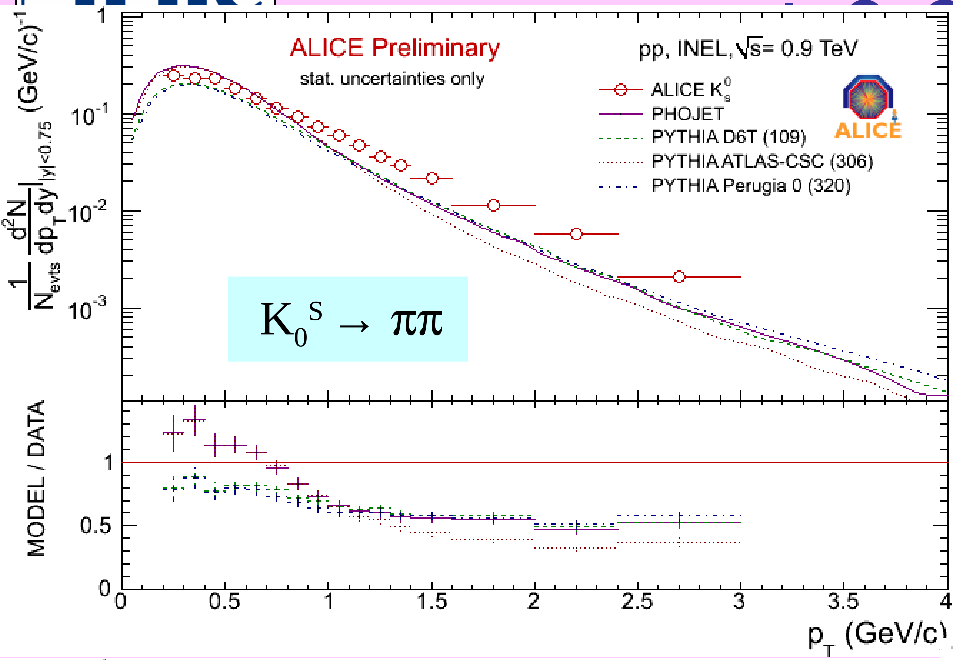


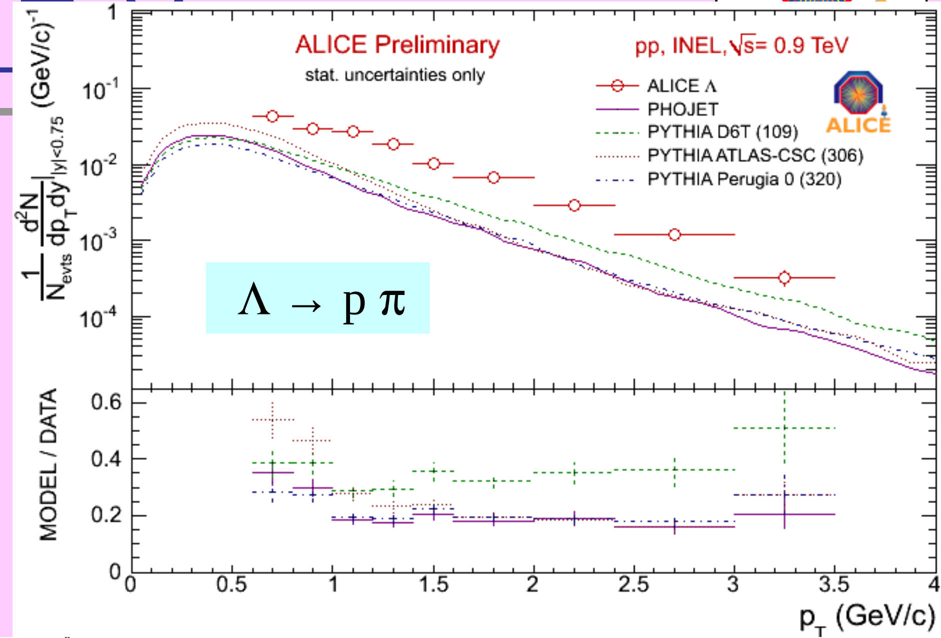


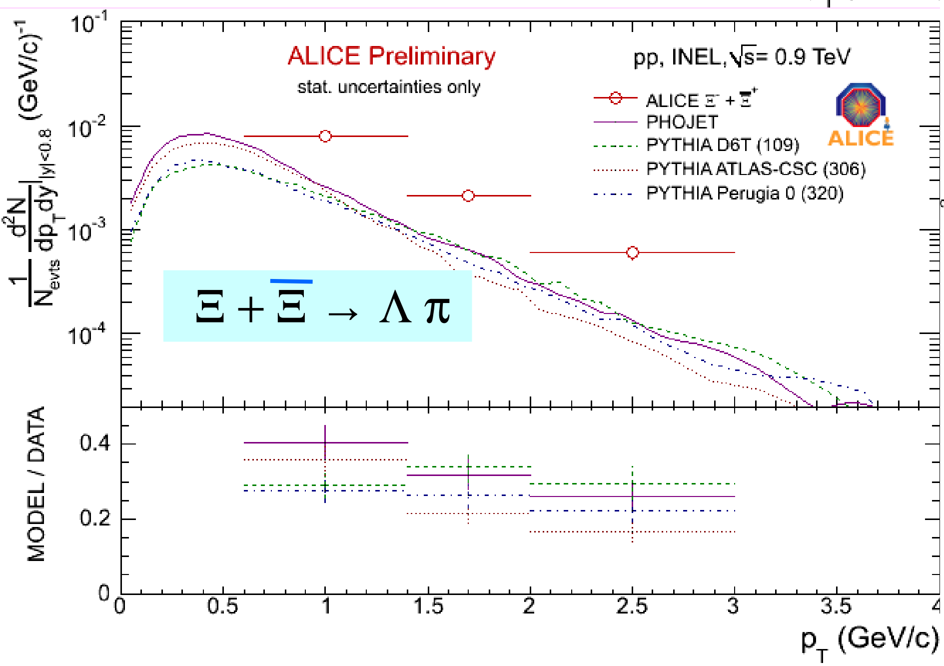


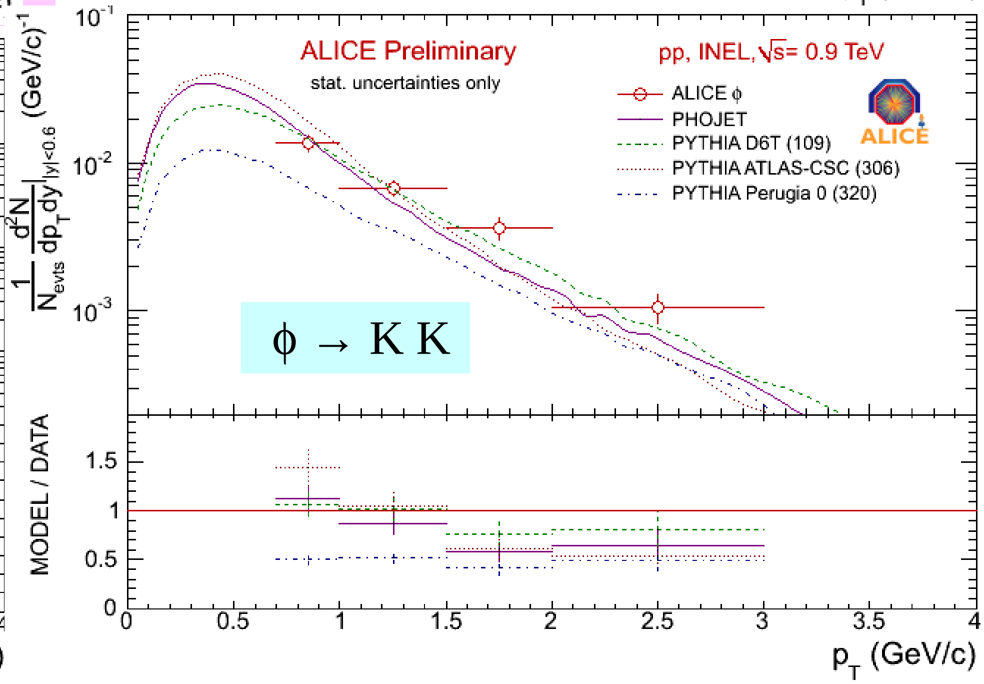


Strange particle spectra

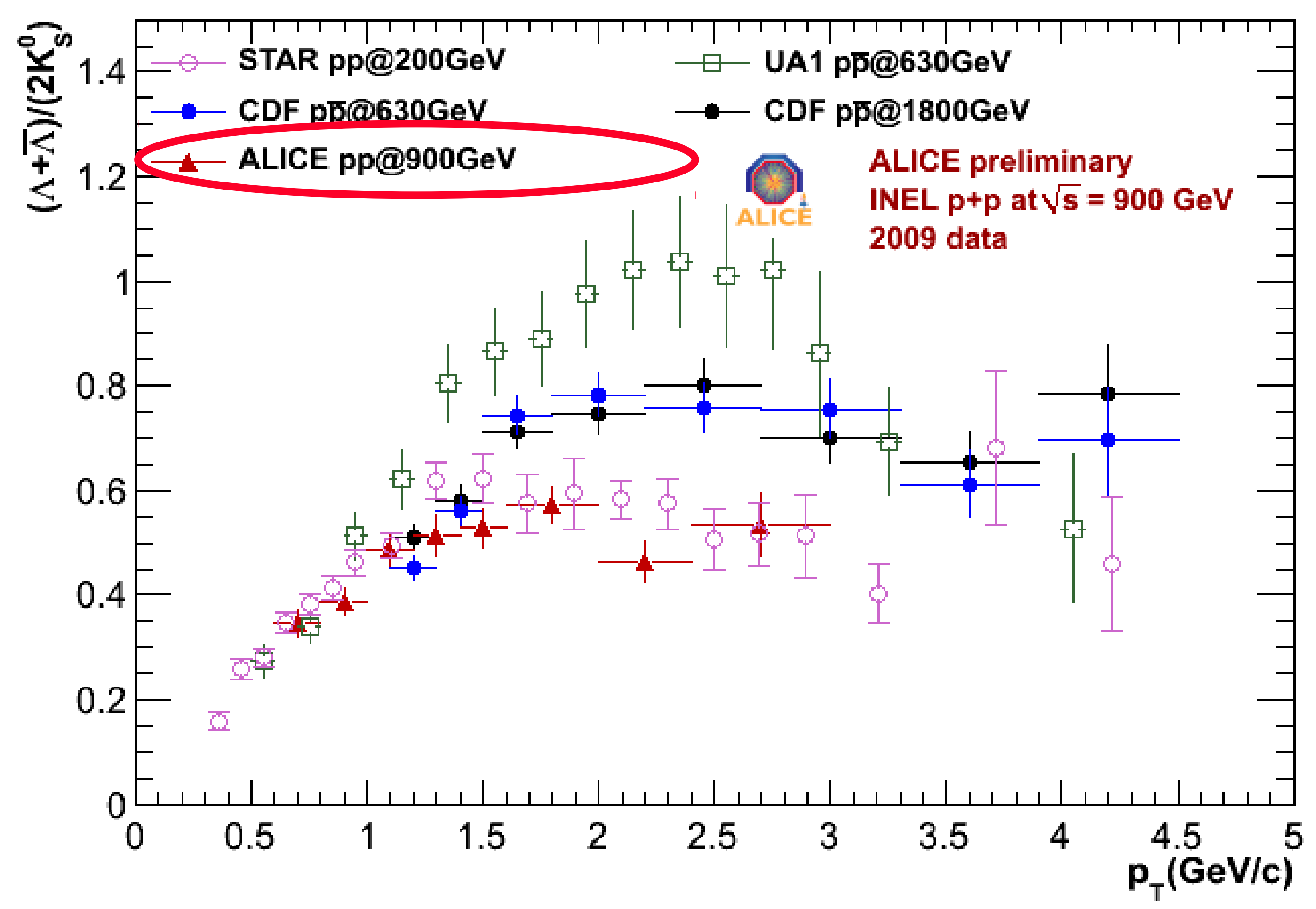








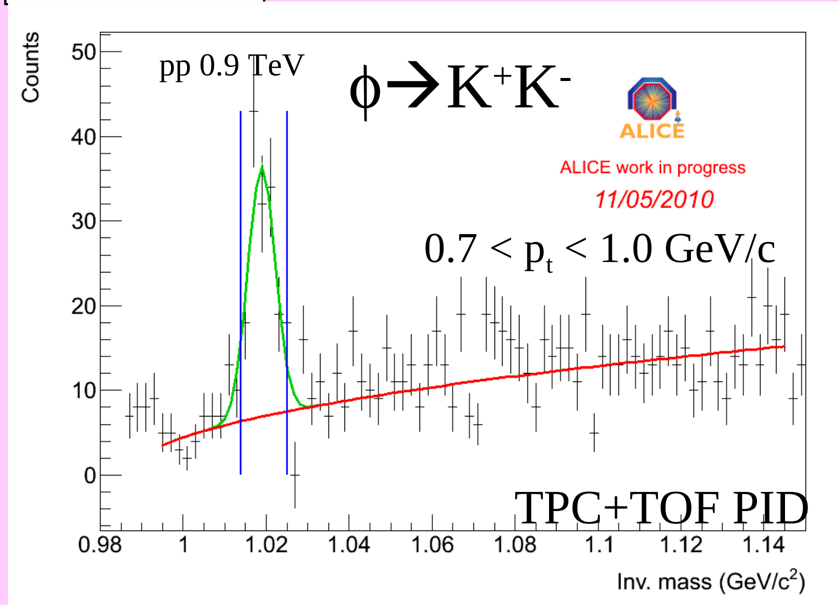
Λ/K^0_S ratio at 0.9 TeV

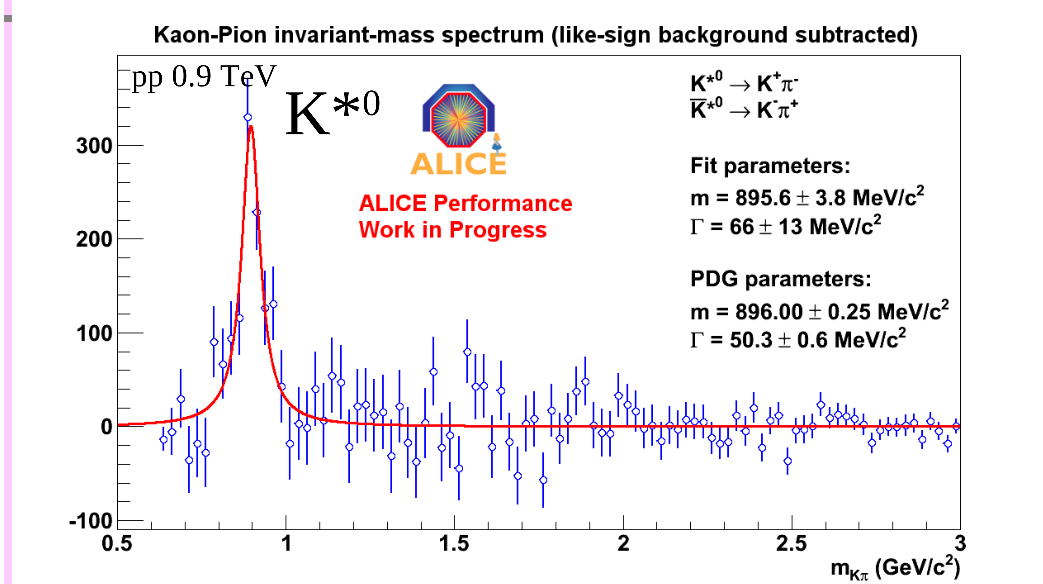


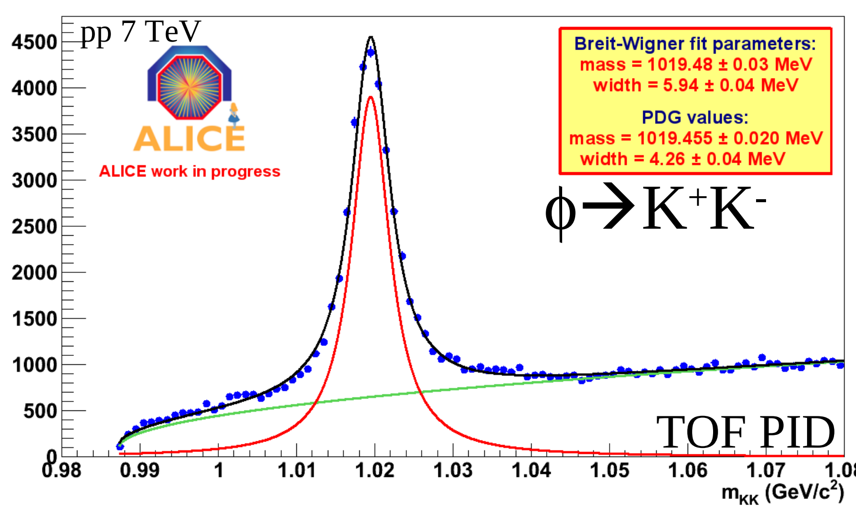
- very good agreement between STAR (200 GeV) and ALICE (900 GeV)
- very different from CDF (630/1800) and UA1 (630) for $p_T > 1.5$ GeV
- UA1(630) and CDF(630) don't agree either …

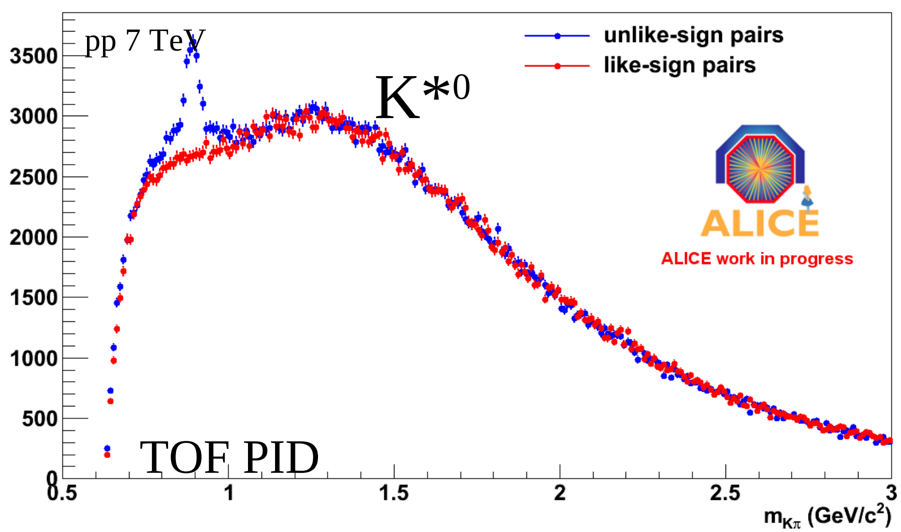
to be further investigated (different triggers, acceptance, feed-down correction ?)

φ and K^{*0} at 0.9 and 7 TeV



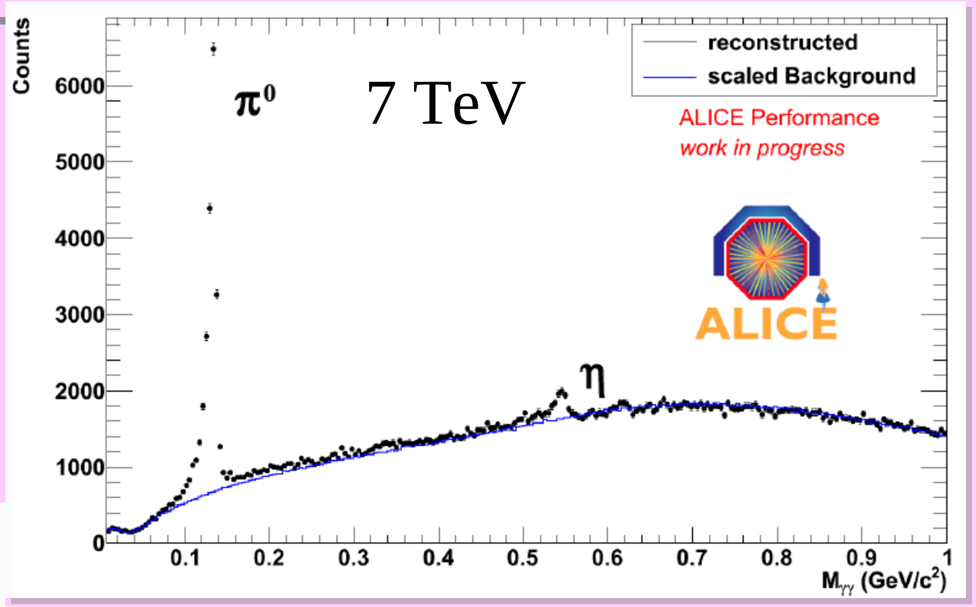


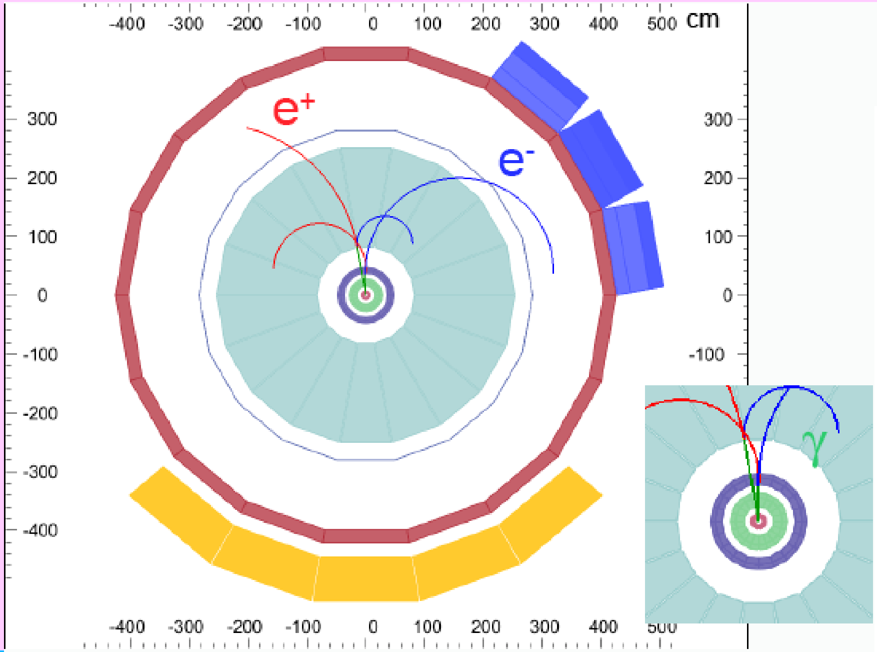


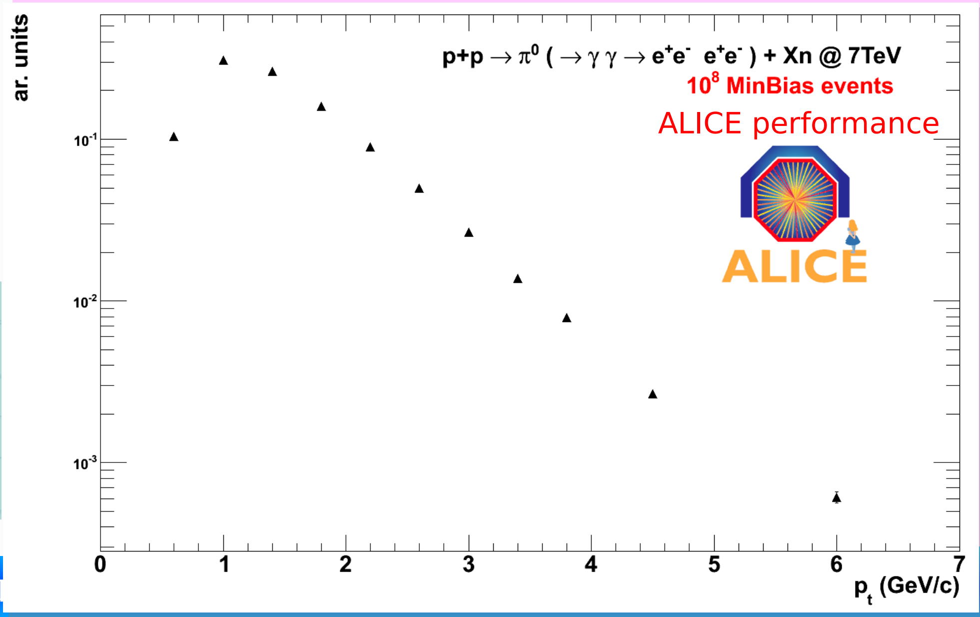


Prospects for π^0: conversions

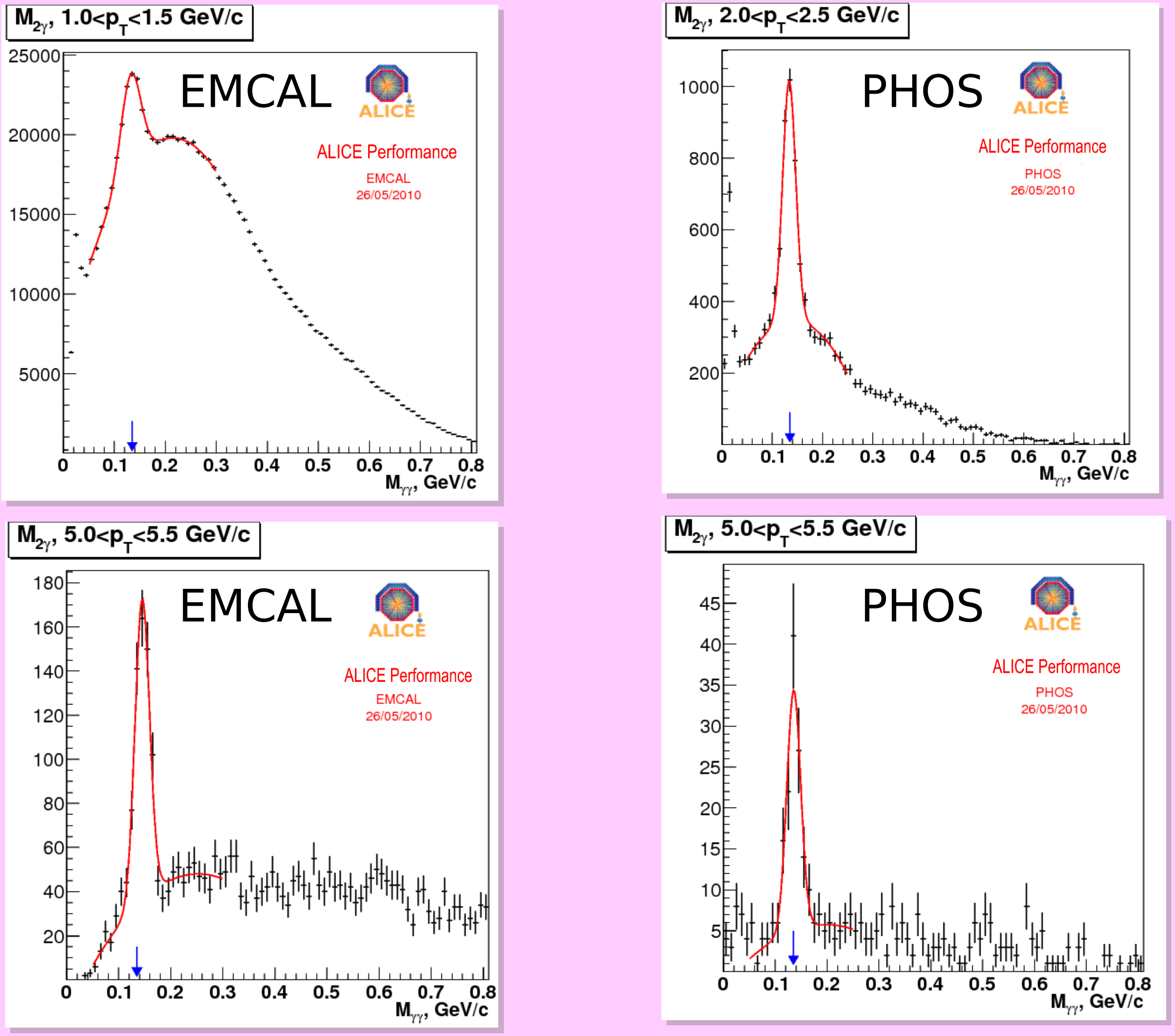
- Electron ID in TPC
  - TRD to join soon
- Conversion reconstruction in TPC+ITS
  - also very important for material budget scan
- For π^0 and η: double conversion



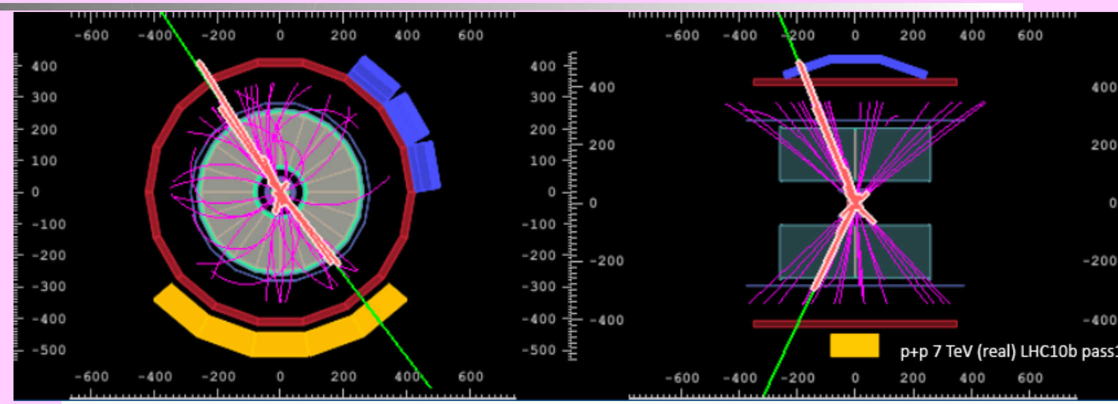




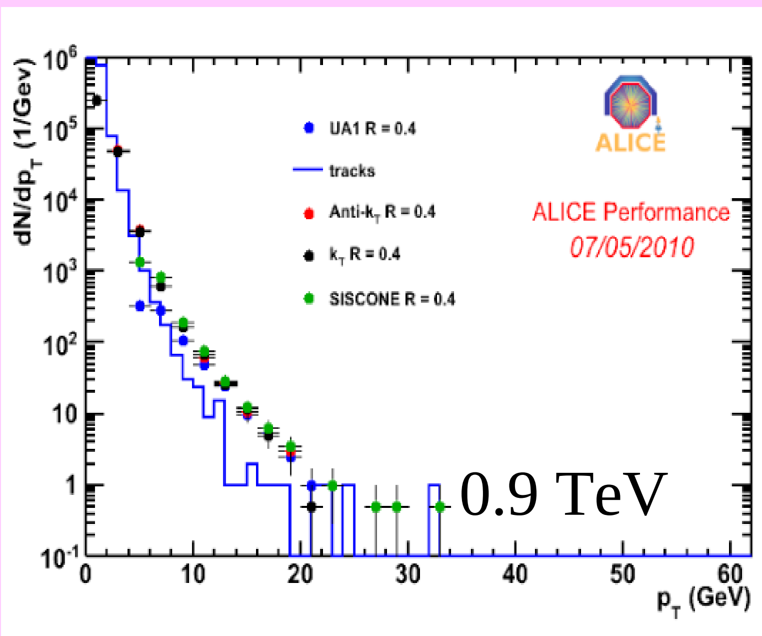
Prospects for π^0: calorimeters

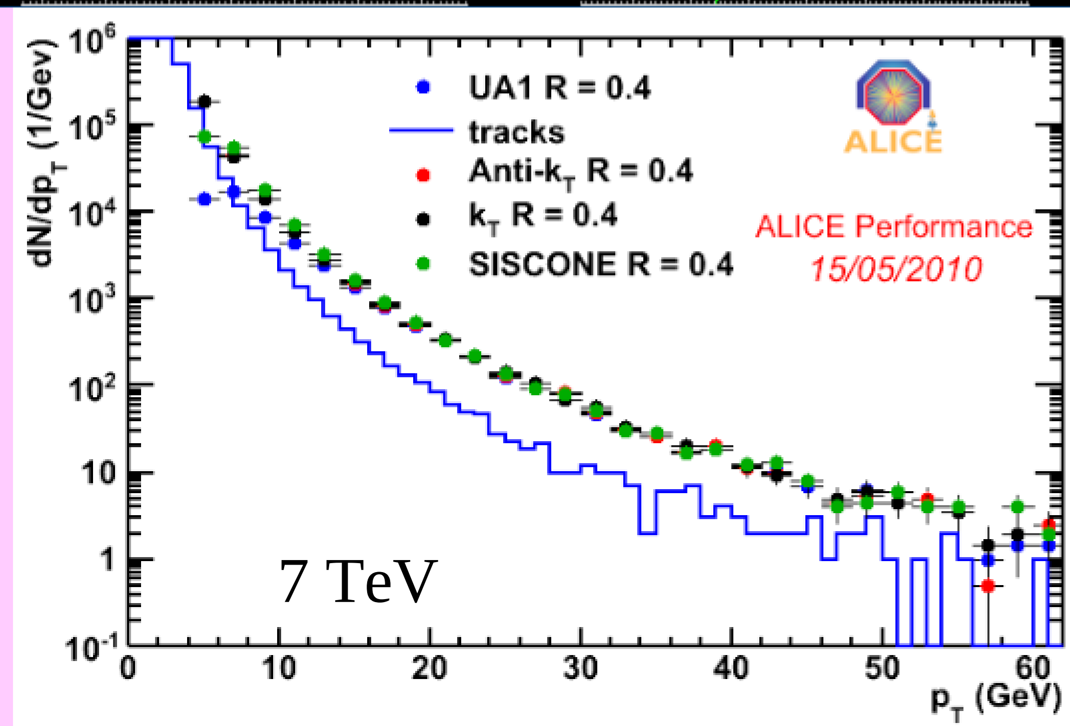


High p_T and Jets

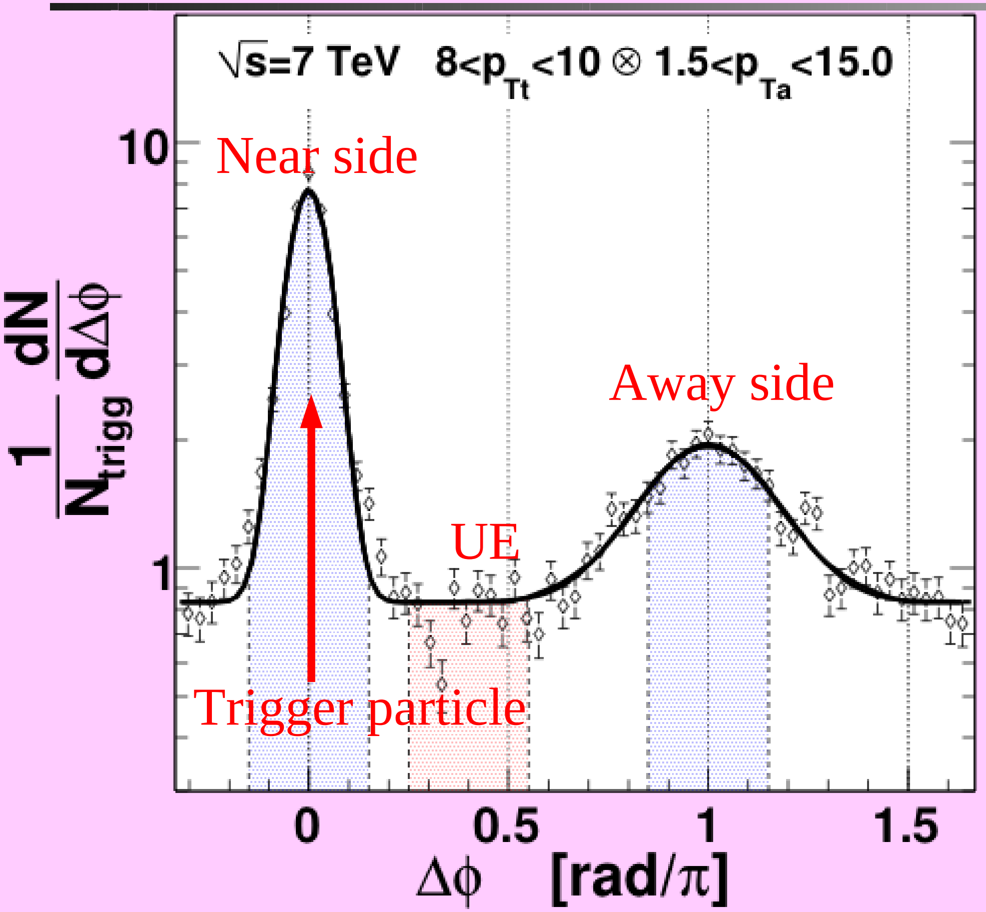


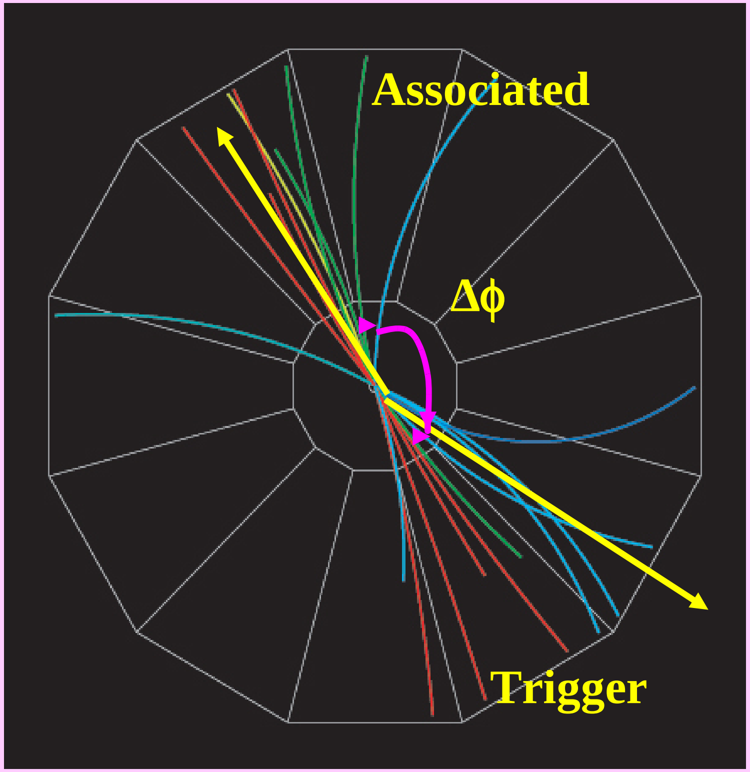
- Charged-track jets raw spectra 0.9 and 7 TeV
  - $|\eta|<0.5$
  - Four jets algos compared
  - uncorrected





High p_T particle correlations

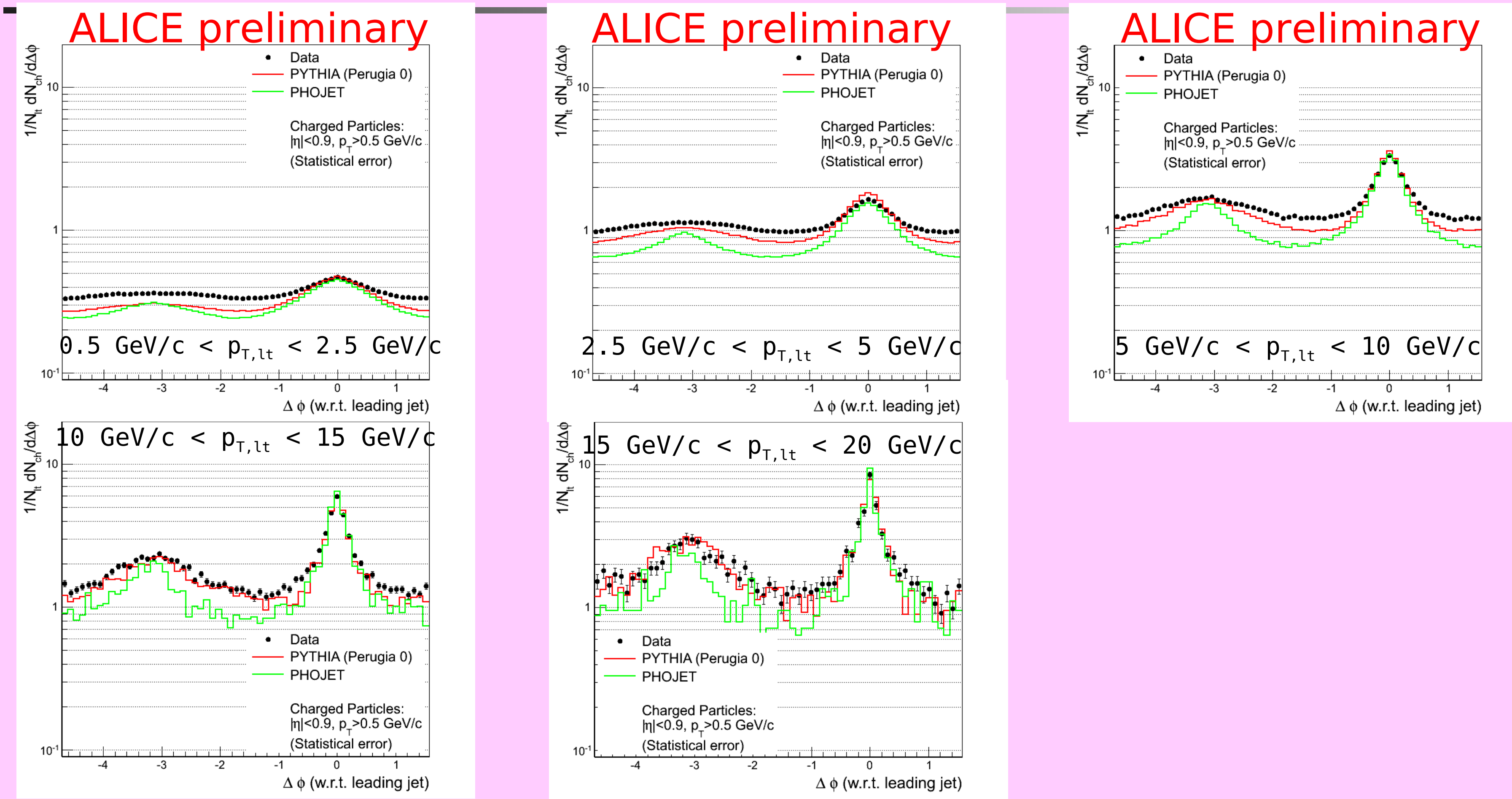




Trigger Particle: highest p_T particle in event (p_{Tt})

Associated Particle: all the others (p_{Ta})

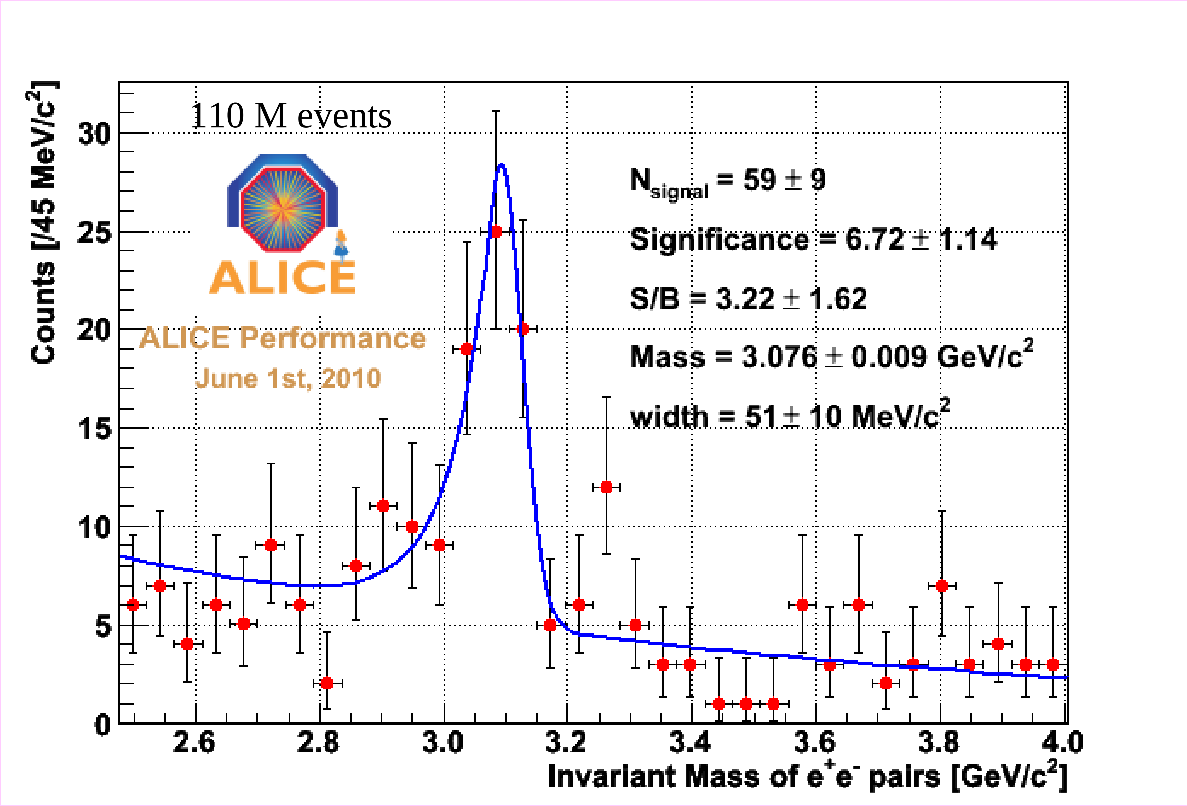
High p_T, UE structure *vs* MC

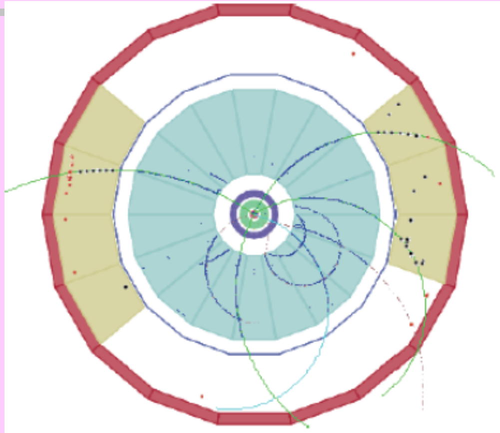


- Inclusive $\Delta\phi$ correlations wrt the leading track
- For p_t<10 GeV/c, the data are less "back-to-back-ish" than MCs

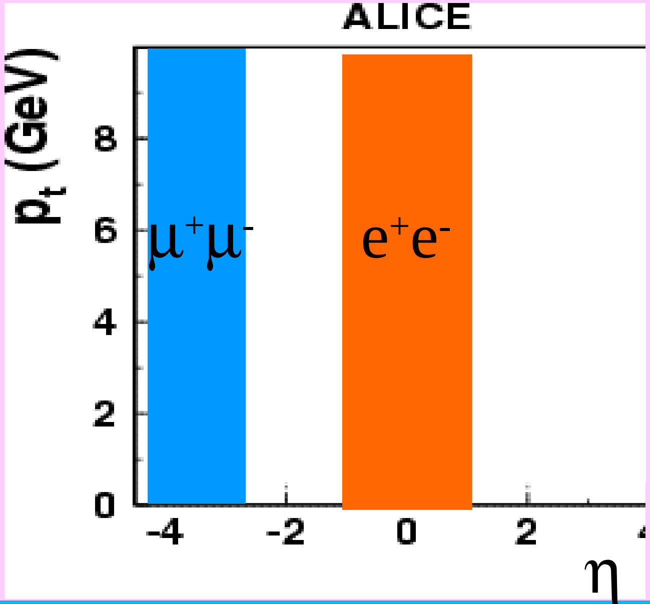
J/ψ→ee, |η|<0.9

- e PID from TPC
  - TRD and EMCAL calibration is ongoing



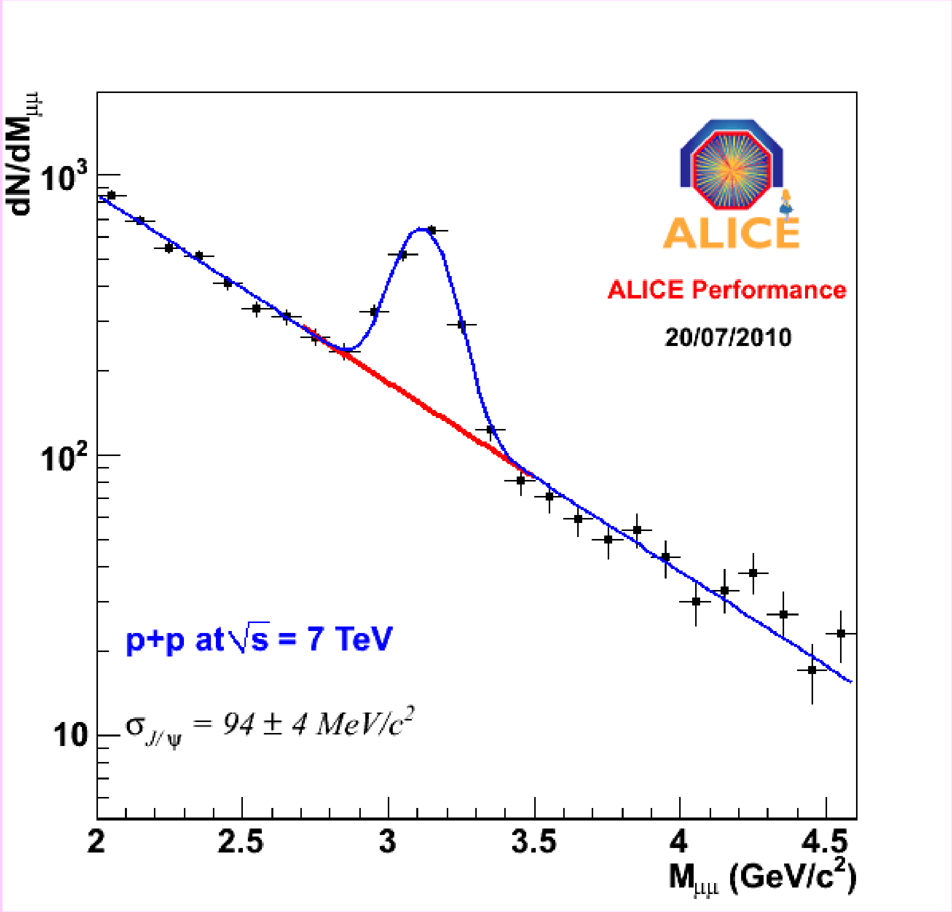


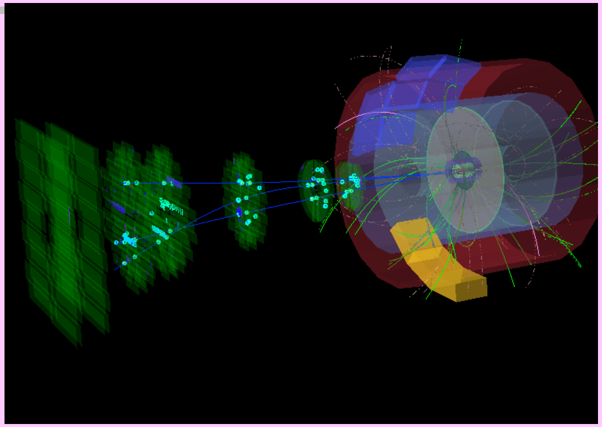
acceptance to $p_t=0$



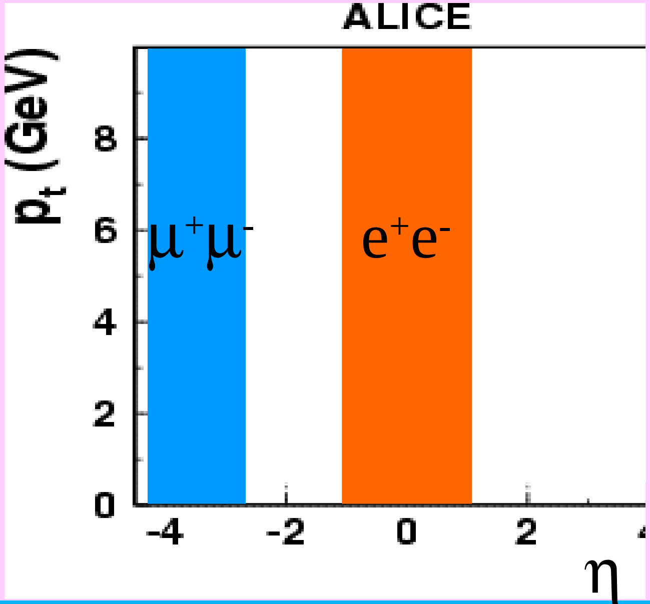
Forward J/ψ→μμ

- $J/\psi \rightarrow \mu\mu$, $-4<\eta<-2.5$

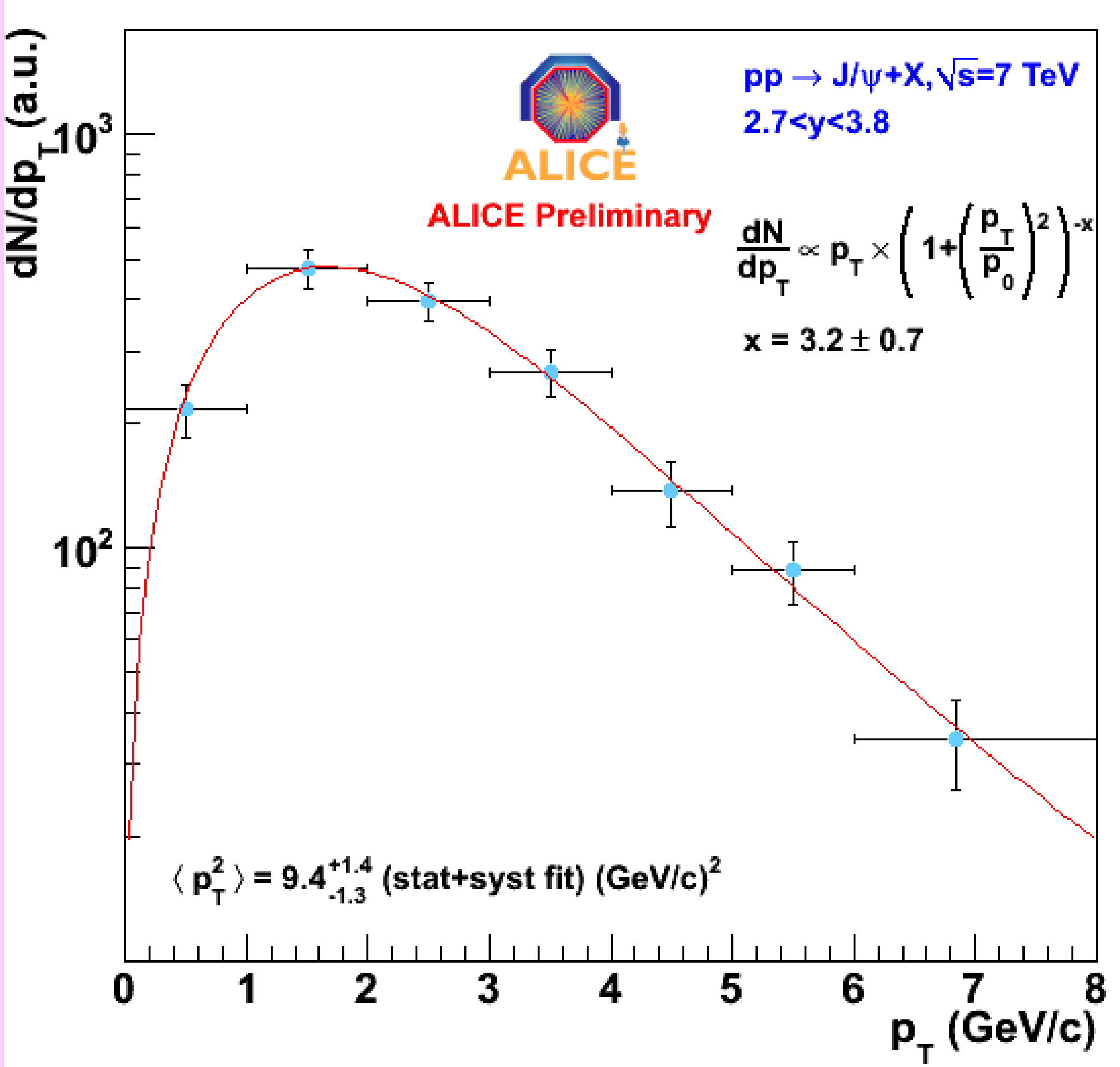


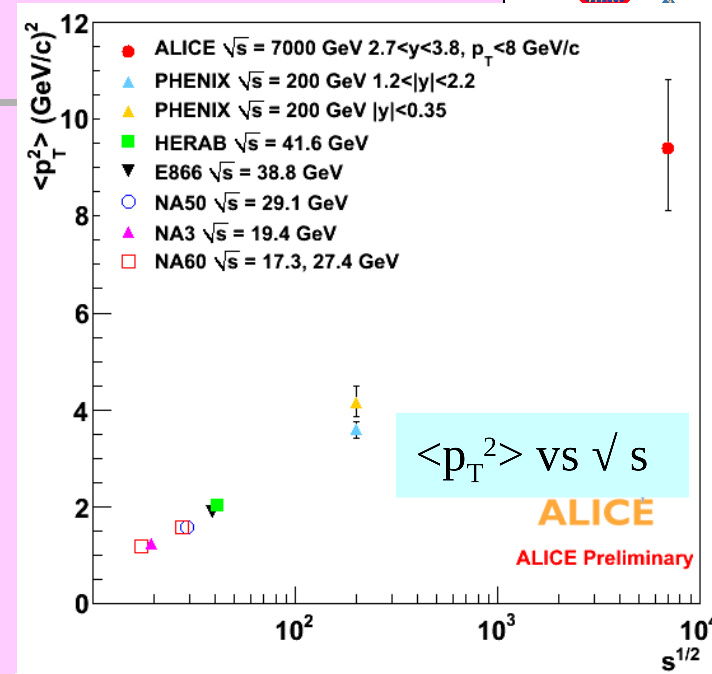


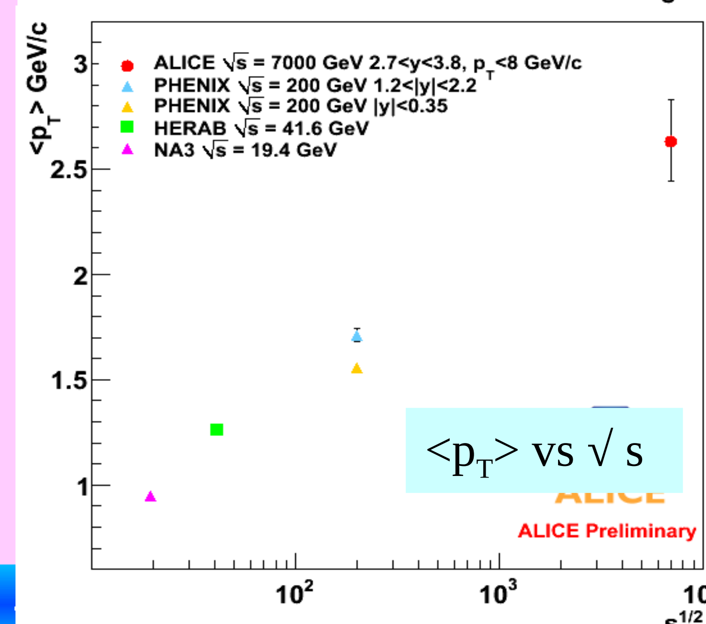
acceptance to $p_t=0$



Forward $J/\psi \rightarrow \mu\mu$

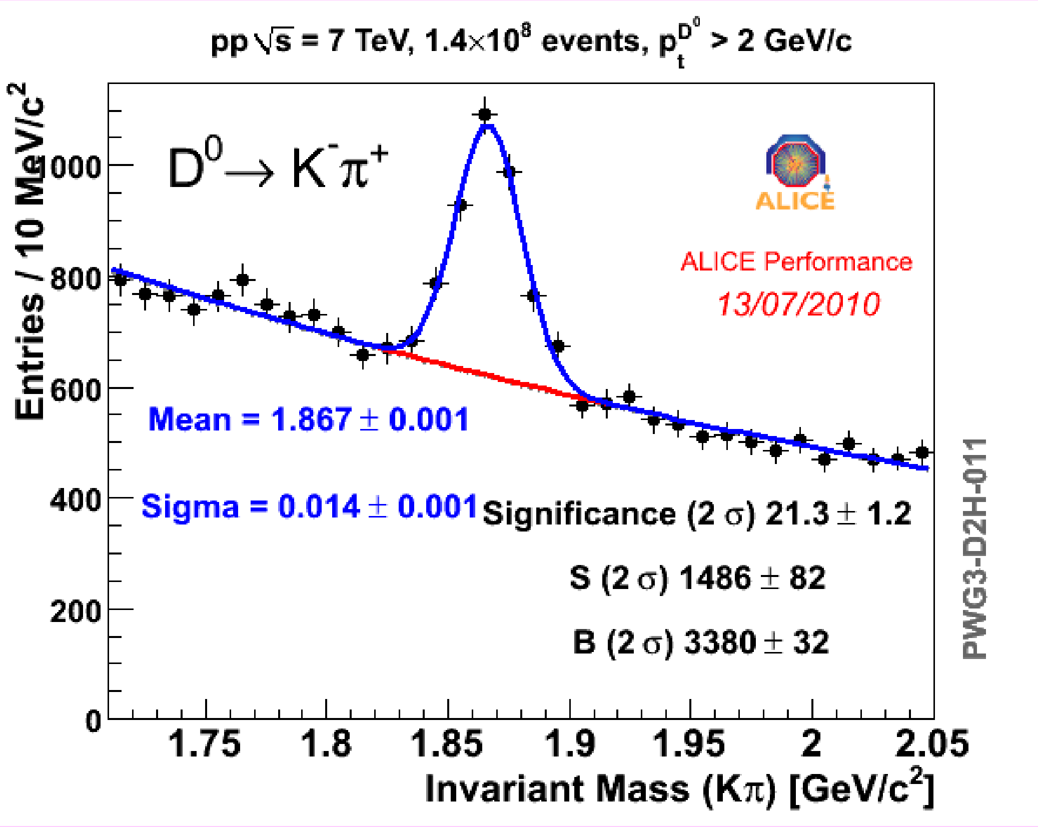


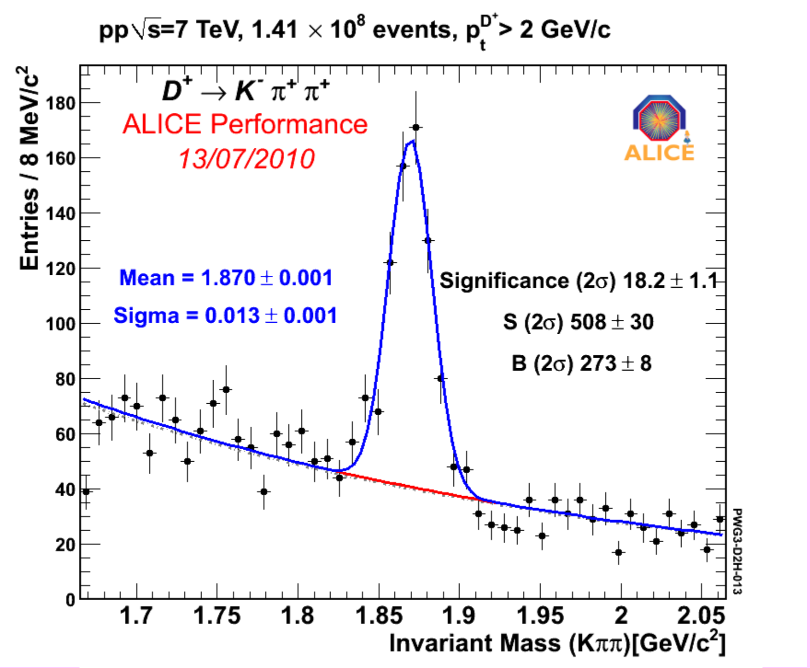


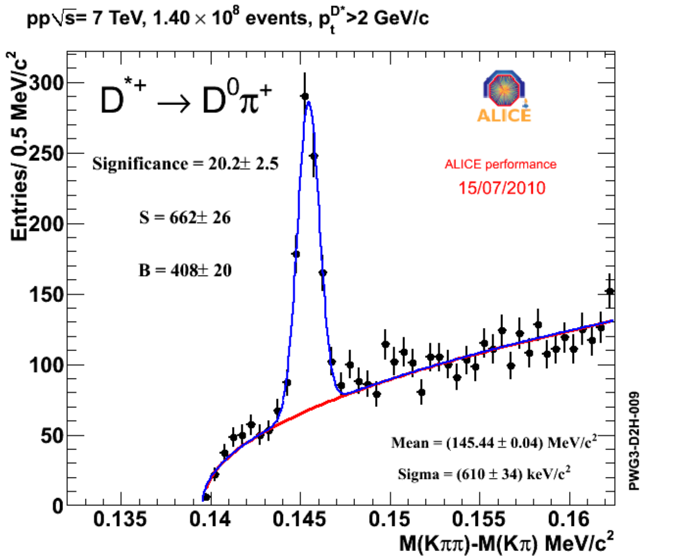


Charm: D^0, D^+, D^{*+} at 7 TeV

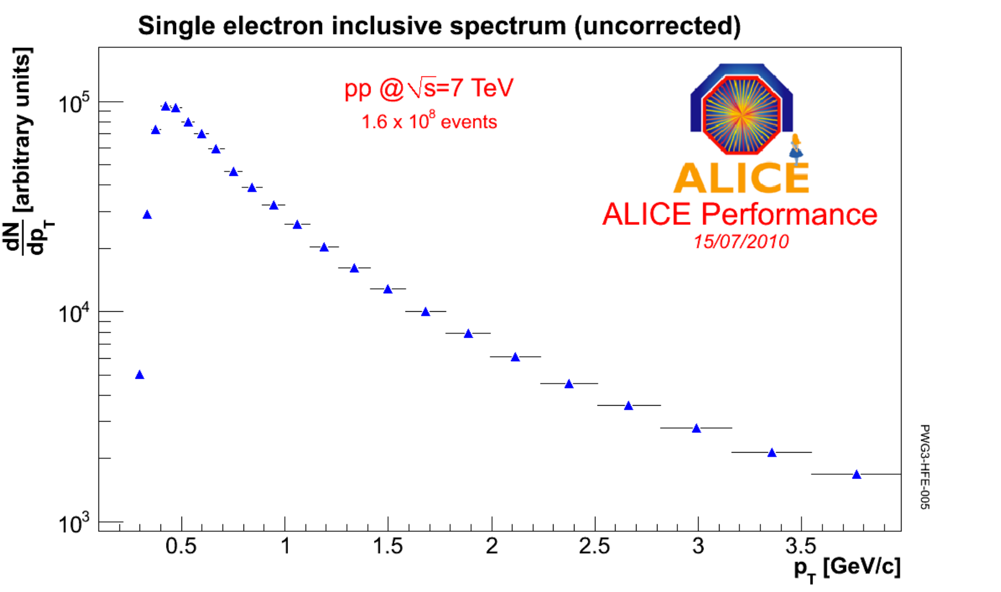
- Signal in the p_T range 1–15 GeV/c
  - compare to pQCD (FONLL) at 7 TeV

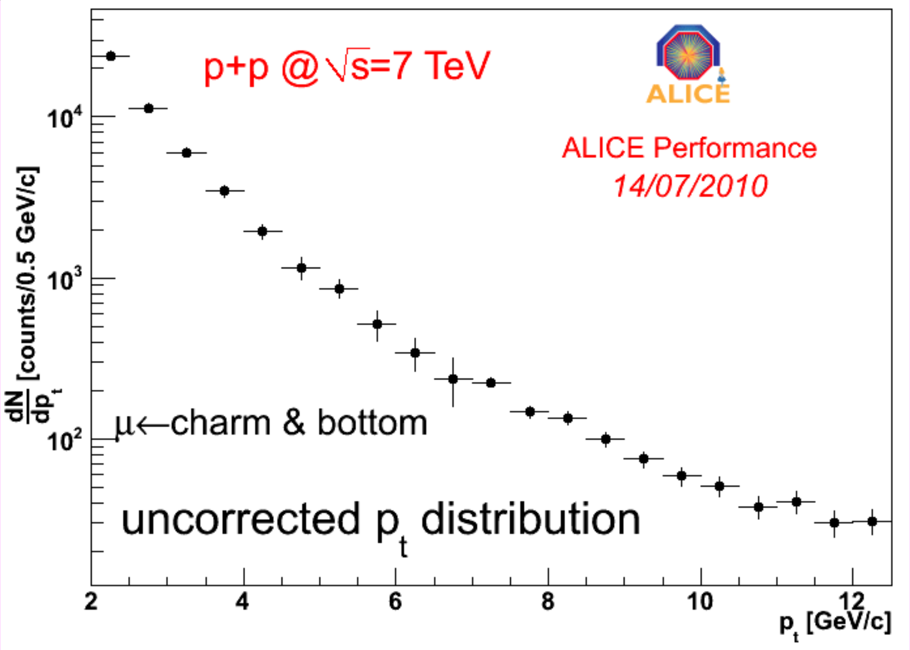






Heavy flavour from single leptons





- Electrons $|\eta|<0.9$
- TPC dE/dx, K and p rejection with TOF
- TRD and EMCAL will join soon
- Displacement selection

- Muons $-4<\eta<-2.5$
- Light quark contribution subtracted with PYTHIA
- c & b to be separated by fitting based on pQCD shapes (in progress...)

First physics results from ALICE

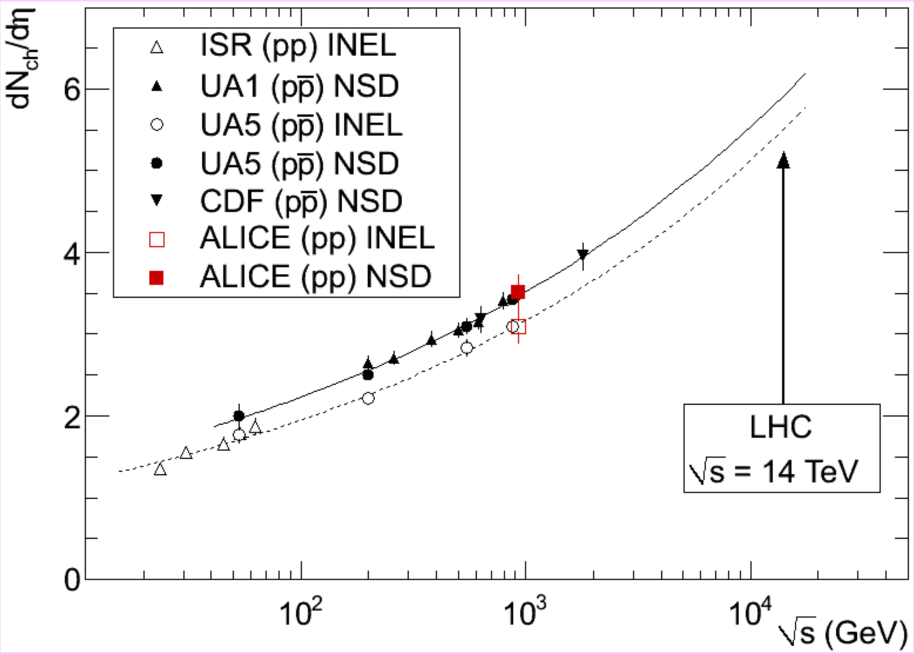
- Particle multiplicity
  - *increase from 0.9 to 7 TeV significantly larger (>20%) than predicted*
- Momentum spectra
  - *$<p_t>$ vs N_{ch} not described by any of the MCs*
- Anti-proton/proton ratio at midrapidity
  - *pbar/p goes to 1 at 7 TeV → baryon number transfer suppressed over large Δy*
- Bose-Einstein correlations at 0.9 TeV
  - *particle emitting source "size" increases with multiplicity*
- Event topology
  - *significant activity outside jets, inside the UE*
- Promising performance for ID spectra, strangeness, charm, charmonium
  - *More strangeness than predicted (except ϕ)*

Extra slides

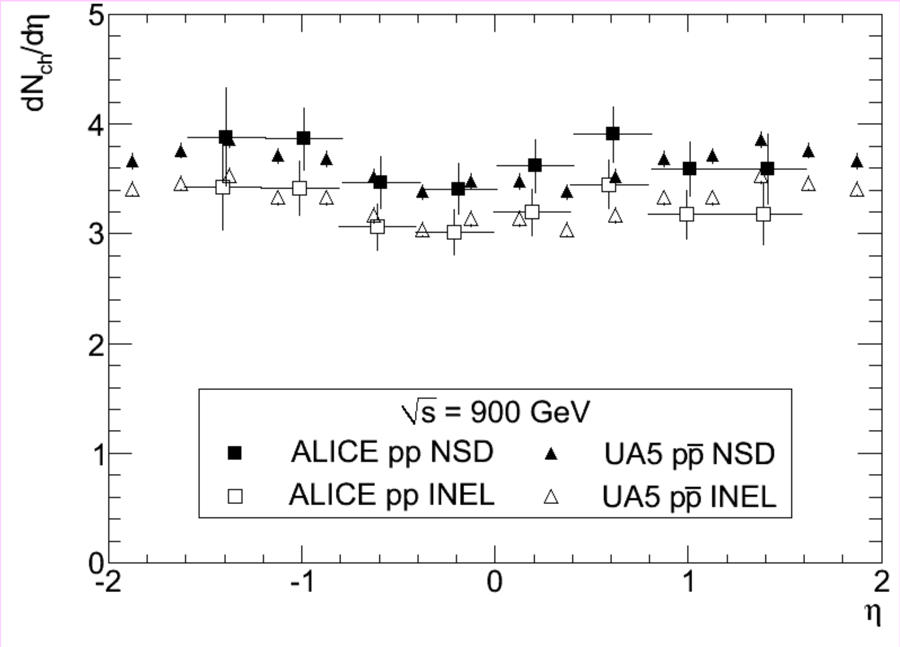
The first paper at LHC

K. Aamodt et al. (ALICE), Eur. Phys. J C 65 (2010) 111

$dN_{ch}/d\eta$ for $|\eta| < 0.5$



$dN_{ch}/d\eta$ vs η



- data collected 23 Nov, paper submitted 28 Nov
- 284 events (~ 3.7 authors per event)

Systematic uncertainties

$dN_{ch}/d\eta$

Systematic uncertainties in %	900 GeV	2.36 TeV	7 TeV
Fractions ND/DD/SD*	0.5	0.3	1.0
MC dependence	+0.8	+1.5	+2.8
Detector efficiency	±1.5		
Particle composition**	±(0.5 - 1.0)		
Material budget	negl.		
p_T spectrum	±0.5		
SPD triggering efficiency	negl.		
V0 triggering efficiency	negl.		
Background	negl.		

* Fractions changed at 0.9 and 2.36 TeV like in paper 2; at 7 TeV by 50%

** η-dependence

Unfolding using χ^2-Minimization

$$\chi^2(U) = \sum_m \left(\frac{M_m - \sum_t R_{mt} U_t}{e_m} \right)^2 + \beta R(U)$$

- One free parameter per bin for unfolded spectrum U_t
- Regularization
  - Prefer constant locally
  - Prefer linear function locally
- Weight parameter β needs to be tuned
  - χ^2/ndf not larger than 1
  - Keep bias low

Regularizations

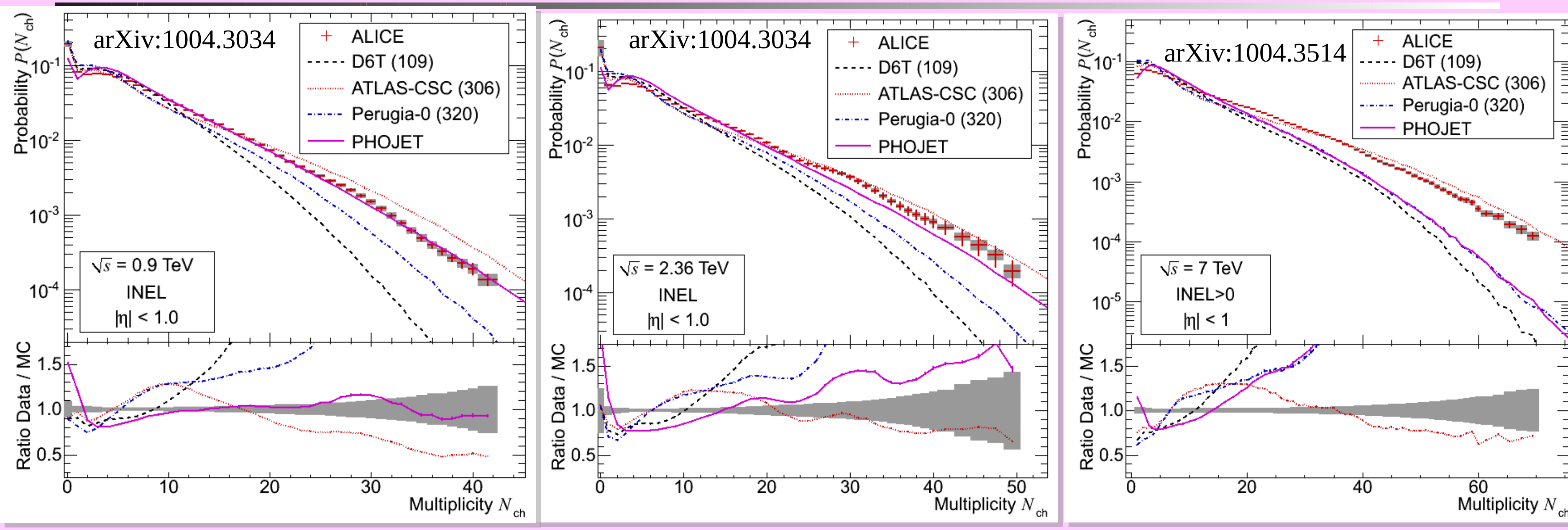
$$R(U) = \sum_t (a_t)^2$$

$$a_t = \frac{U'_t}{\sqrt{U_t}} = \frac{U_t - U_{t-1}}{\sqrt{U_t}}$$

$$a_t = \frac{U''_t}{\sqrt{U_t}} = \frac{U_{t-1} + 2U_t - U_{t+1}}{\sqrt{U_t}}$$

V. Blobel, Yellow report, 1984

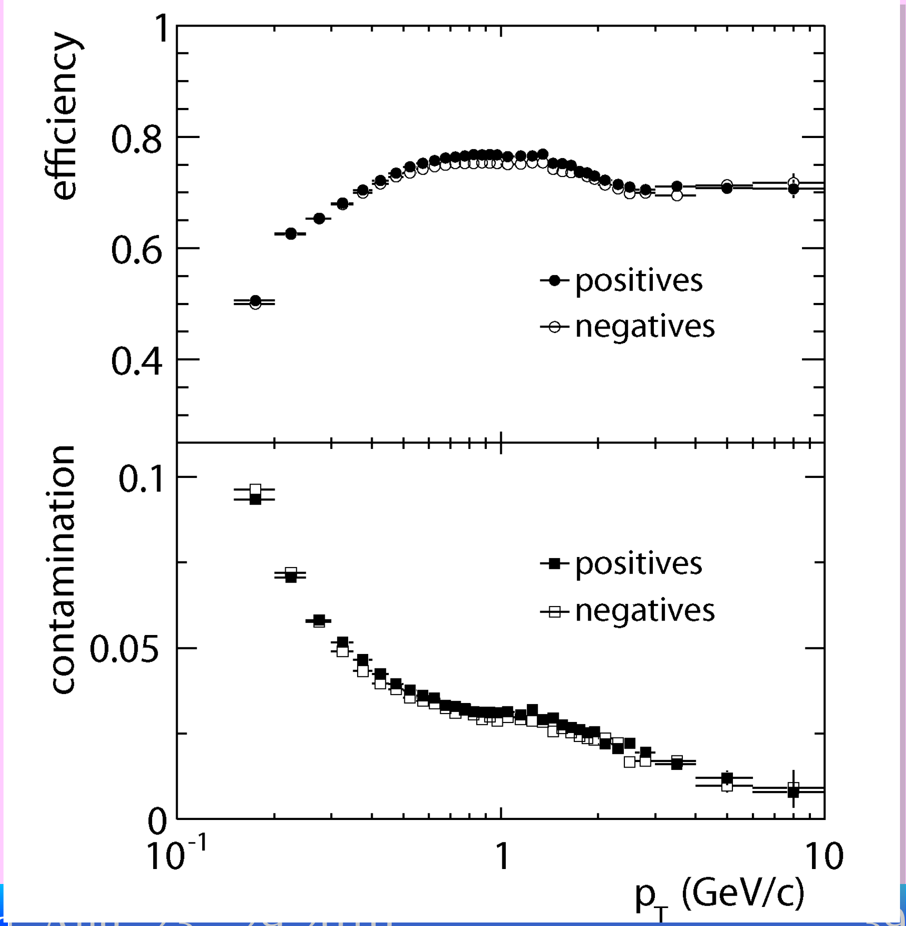
dN/dN$_{ch}$ *vs* Monte Carlo



- Phojet
  - provides a good description at 900 GeV
  - fails at 2.36 and 7 TeV
- Pythia Atlas CSC
  - fails at 0.9 TeV
  - reasonably close at 2.36 and 7 TeV but deviations around 10-20
- Pythia D6T and Perugia-0 far from the distribution at all energies

Charged particle p_T spectrum

- Track reconstruction in TPC (≤160 hits) +ITS (≤6 hits)
  - p_t measurement from TPC only (ITS-TPC alignment not final)
    - $(\sigma(p_T)/p_T)^2 \approx (0.01)^2 + (0.007p_T)^2$ %
- Track selection:
  - p_t > 150 MeV/c, $|\eta|$ < 0.8
  - $nhits_{TPC}$ > 70, χ^2/hits<4 in TPC
  - at least 2 matching hits in ITS
    - at least 1 in SPD
    - 4.7 on average
  - cut on transverse impact parameter (7σ)
- From MC, cross-checked with data:
  - Efficiency 50-80%
  - Secondary cont. 9-1%



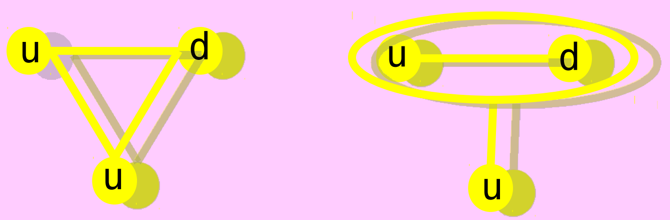
Baryon number at midrapidity

- Valence quarks: Rossi and Veneziano, NPB123 (1977) 507
- Gluonic field: Kopeliovich and Zakharov, ZPC43 (1989) 241

Conventional approach - QGSM

Within QGSM one expects an asymmetry ~0 at LHC energies

❑ No BN transported at mid-rapidity from the fragmentation region

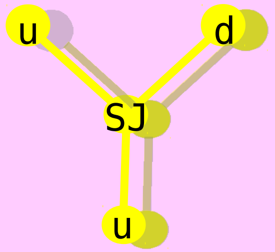


String Junction

BN transport even at large rapidity gaps (large energies).

❑ Veneziano: Probability exponentially suppressed (a_J: SJ intercept – model dependent)

❑ Kopeliovich: Probability constant with rapidity



D^0 meson reconstruction

- Main selection: displaced-vertex topology
- Example: $D^0 \rightarrow K^- \pi^+$
  - good pointing of reconstructed D momentum to the primary vertex
  - pair of opposite-charge tracks with large impact parameters
- Kaon ID in TPC+TOF helps rejecting background at low p_t